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THE PROGRESS OF RESEARCH IN AGRICULTURAL ECONOMICS IN THE UNITED STATES*

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The thought that stands out most conspicuously in my mind as I start to read this paper is that most of you who are listening to it are workers in the applied natural sciences of agriculture—agronomy, animal husbandry, horticulture, biochemistry, phytopathology and the like—and that my responsibility as well as my opportunity is to make my discussion of the progress of research in agricultural economics at the same time give you a clear idea of the nature of research in this field and its difficulties and limitations.

Any candid worker in agricultural economics, as well as in the social sciences generally, who understands the subject he is discussing, will admit that research method in his field is still in the early stages of its growth. This is partly because these sciences, considered as subjects of research rather than as pure speculation, are still very young; and partly because of the great difficulties of measurement involved. I am aware that many workers in the natural sciences consider the problem of measurement in the social sciences so nearly impossible of solution that social problems cannot really be studied scientifically, and that there is no such a thing as a social science. But it must be admitted that truth is sometimes arrived at with respect to social problems as well as to problems of the physical universe. Then there must be some method by which truth is attained in such matters. It is the task of students in the social sciences to discuss and define and classify these methods, observe their essential modes of procedure, their successes and failure and the reasons for them.

It must be freely admitted that some of the research methods used in the past, and still being used by many, I regret to say, do not lead to sound conclusions; that too many things affirmed in the past as truths following research in this field have later been found to be untruths or only part truths. But this does not mean that truths can never be successfully established in the social field. Instead, it points to the need for a careful study of methods. It was the realization of this that led to the establishment of the Social Science Research Council a few years ago, and later to the setting up of a special subsidiary committee to consider methodology for problems in agricultural economics and rural sociology. The members of this sub-committee are as follows: H. C. Taylor, chairman; E. G. Nourse,

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in charge of the agricultural section of the Institute of Economics, Washington, D.C.; John D. Black, Harvard University; L. C. Gray, in charge of land economics in the U. S. Department of Agriculture; J. S. Davis, one of the directors of the Food Research Institute, Leland Stanford, California; C. J. Galpin, in charge of farm population and rural life studies in the U. S. Department of Agriculture and F. A. Pearson, Cornell University. This committee holds its third annual session in Washington beginning June 14th. Its three principal achievements thus far are to make a survey of research in agricultural economics and rural sociology in order to discover its present status and needs, to secure an appropriation of $30,000 a a year for five years for fellowships in these two fields, and to promote the preparation of two handbooks of research method, one for rural sociology and one for agricultural economics. These will be completed by the end of the summer.

The problems which research in the social sciences has to handle are essentially of the same logical types as those in the natural sciences. In broad outline, scientific method is the same in all fields. There is the same isolation of the problem, the same setting up of the hypothesis, the same definition of the units, the same securing of the sample for study, the same exclusion of extraneous considerations, the same measurement of the varying factors and measurement of the results, the same inferences from the results, etc. The differences are largely in the details of procedure at the various steps. For example, in the natural sciences, the usual procedure is to set up a special hypothetical case in which most of the conditions are under control, whereas in the social sciences the usual procedure is to examine a sample of already existing or historical cases with conditions varying widely between them and attempt to measure these varying conditions. In practice, it will seem that social scientists are giving special attention to certain phases of procedure. But this merely follows from the fact that these particular steps are more difficult in the social sciences. The attention being given to measurement of economic value by economists, or to mental measurement by psychologists, illustrates this point amply.

It will also appear that the social scientists are making much more use of the statistical method than are the natural scientists, and little use of the experimental method. Logically there is no difference between these two attacks—the difference is in mechanics of isolating the effect of a variable. Experimental method of a sort, in which only part of the influences are under control, and those not under vigorous control, is coming into more use in the social sciences; but it will never be widely used, and for obvious reasons. It will always be necessary to take phenomena pretty much as they are found and attempt to isolate the various influences on the result *after* the result has happened. It is also proper to point out that the actual results in such cases often reflect many influences, making needful the measuring of many variables, so that the problem is inescapably complex. It is not possible with such a method to break the problem up into parts or steps as in the experimental method and attack one at a time; it must be attacked as a whole and at one time.

Another difference is the importance of the time element in social research. Pure unalloyed time, flowing smoothly and without an eddy, complicates nothing. It is the succession of ups and downs and waxings and wanings that become associated with the passage of time, that give such a science as economics its major problems. The science of economics heretofore has been too much a static science. It has yet to develop a systematic body of laws relating to change. Adjustment to changing economic conditions is the keynote of research in agricultural economics at the present time.

Research in economics has a strong qualitative content. One cannot analyze profits without a theory as to the origin of profits—land values without a theory of land values. Perhaps it is not so different from physics and chemistry in this respect as at first appears. It is to be doubted if any hypothesis ever set up in economics is the equal of the ether hypothesis of the physicists. In the field of pure economics, the order of progress has been to develop a body of theory first, and only lately has quantitative analysis come strongly to the fore; in the field of agricultural economics, the order of progress has been the reverse of this. We have had tons and tons of data collected without much of an understanding of the problems to which they have applied.

Research in agricultural economics is confronted by the special difficulty that the units of observation, the family farm, the local marketing agency, etc., are small and make few records of their activities; also a large proportion of the economic decisions pertaining to agriculture focus around the individual farm as a center and are remote from actual markets where decisions are translated into monetary valuations. The close relationship between the producing and consuming activities of the farm family is a further difficulty.

The significance of the foregoing will be more apparent if we consider the progress of research in some one economic field taken as an example—and that field had best be the economics of agricultural production because this is nearest to your experience and has had the longest history. The early research work in this field followed two lines principally; namely, cost of production analysis, and farm survey analysis. There was agricultural cost of production analysis before 1900; but it began in earnest in 1902 when Minnesota started its first cost route and Dr. W. J. Spillman went to the U. S. Department of Agriculture. When the Office of Farm Management was developed in 1905 with Dr. Spillman in charge, cost of production analysis became its major activity. It grew rapidly at Minnesota, Cornell, Wisconsin, and other places, reaching its climax during the war and just following, when Dr. H. C. Taylor went to Washington to succeed Dr. Spillman as chief of the Office of Farm Management, and the price-fixing activities of the Government aroused the interest of farmers and Congressmen in cost of production as a basis for price fixing. There is a vast program of cost of production analysis still under way in the United States. The recent general expansion of research in agricultural economics following the passage of the Purnell Act has probably increased

absolutely the volume of cost of production analysis. But relatively, it has declined a great deal. Moreover, the objectives and points of view have changed greatly. The U. S. Bureau of Agricultural Economics has withdrawn all its support to cost routes in the States, and its own analysis is no longer along the lines of unit cost of production as a basis for choosing enterprises.

At this point, it will be well to distinguish closely between cost of production analysis in particular and cost analysis in general. Cost of production analysis as carried on in the United States looks to the end of a composite unit cost figure—for example, $1.53 per bushel as the cost of producing wheat, in which the amounts of man labor, horse labor, machine use, seed, fertilizer, land use and all the other input factors, are converted to a money basis and added. (The unit may be the acre instead of the bushel.) There is room for a vast program of cost analysis which does not attempt to compute such a composite cost figure. Thus the feed cost of milk may be analyzed by itself, or the fertilizer cost of cotton. This analysis can be left in purely physical terms—the relation of units of feed input to hundredweights of milk; of inputs of fertilizer to bales of cotton. But if money rates are available, as they are for commercial fertilizer, then it is possible to convert the costs to a money basis. In this case, the feed or fertilizer costs may vary from farm to farm because of differences either in inputs or in buying prices; and it is important to know which, and to have separate data for each. Man-labor costs can be analyzed in terms of amounts of labor used per acre and per bushel; or per cow and per hundredweight of milk; or better still, in terms of the number of harowings or cultivations. The effect of substituting tractors for horses, or combines for headers, can be analyzed. It is cost analysis in this latter sense, rather than in the specific sense of composite unit costs, that the U. S. Bureau of Agricultural Economics is interested in these days—and this is the direction of growth out in the States.

The theory upon which the old type of cost of production analysis is set up in that a farm business can be cut up into a number of separate enterprises, costs and profits and losses determined for each and, on the basis of these, the relative profitableness determined, and the most advantageous combination of products. The present attack on the problem of combinations of enterprises is to assemble the data as to prices, yields, out-of-pocket costs, and conflicts between enterprises which are necessary to compute the effect on the net income of the farm as a whole of various combinations of enterprises. If flax is substituted for wheat, how will the cash receipts be different? How will the out-of-pocket expenses be different? How will the net cash income be affected? What will happen to net incomes if a dairy farmer decides to feed more of his corn to hogs and keep fewer cows? This form of attack recognizes the true organic nature of the farm business; that any carving of it into parts is done on arbitrary lines, and produces results necessarily as arbitrary as the basis of separation.

You may say that this procedure does not take account of all the factors in the problem. For example, one crop may take more plant food out of the soil than another. This is true, but no cost of production analysis has ever taken account of this. In fact, in nearly all of such analysis, the same rent charge is used for all crops. It is as possible to include an allowance for this factor under the new method as under the old. You may say that keeping more hogs and fewer cows will reduce the amount of family labor, and that this is not provided for under the new method of analysis. The answer is that it is not really provided for in the cost of production analysis. All that is done is to apply some arbitrary rates to it. No intelligent farmer would decide to reduce his number of cows because he saved $40 worth of family labor thereby, the $40 being obtained by applying an arbitrary rate of 20 cents per hour to 200 hours of such labor.

It may be well at this point as later to make clear the scientific value of cost of production results. You men working in the natural sciences have undoubtedly seen an abundance of these cost figures. You have sometimes seen cost of production figures expressed in fractions of cents. No doubt some of you, with the habits of precision you have learned in your own research work, have been skeptical of these figures. I doubt if any of you have been half as skeptical as you should be. Cost of production by definition is the sum of the values of the input factors. A money cost figure is as accurate as the data of physical quantities of the inputs and the money values of them. Let us forget about the difficulties with the data of physical quantities—how they vary with the weather and the yields—and consider values only. Value in the sense here involved is a strictly economic concept. Most of economic theory is concerned with value and its application to various classes of goods and services. No more difficult task can confront an economist than that of determining the value of many classes of goods and service. Since the beginning of the era of the so-called Austrian School of economists, the most generally accepted basis for valuation of goods and services in a cost of production analysis, is that of "opportunity cost", or "alternative use value". The essence of this doctrine is that *things are worth in any use what they would be worth in their nearest competing other use where they are, and as they are.* On this basis, manure that a farmer could sell to his neighbor on the spot at $3.00 a load should be charged at $3.00 per load to the crop to which it is applied instead. If there is no such market for it, however, its value must be based on what it is worth for the nearest competing crop; but what it is worth for the nearest competing crop is as much an enigma as for the crop in question. Under the circumstances that if the farm did not produce the manure, commercial fertilizer would be bought instead, the method of valuation on the basis of the cost of an equivalent in commercial fertilizer is valid; but this circumstance obtains with reasonable exactitude on comparatively few farms. Most of them would buy less fertilizer than this, with what consequences nobody can tell.

On the basis of opportunity cost, labor of man and team that could earn $4.00 a day working on the road should be charged at this rate for the labor it puts in plowing on the identical days—not on any other days. On other days it is worth what it is worth at any other job that might be found—repairing fences, hauling manure, etc. But what it is worth for these tasks is as much of an enigma as the other. Much of the year the proprietor and the members of the farm family have no other important farm use for their time except the one in hand, and often this one is not very important. The alternative on many days is the sacrifice of leisure or recreation. The method of valuing family labor based on what it would cost to hire a substitute represents a serious misapplication of the doctrine of opportunity cost. It does not give the value of the nearest competing use of *this* labor *where it is* and *as it is*. If this family labor could hire out for this sum to a neighbor, and the farm family would be as well satisfied to have it working out as at home, then and then only it is properly valued on the hired-labor basis.

If the question at issue was the broad social one of prices of farm products high enough to keep a supply of farmers on the land, then it would be proper to value proprietor labor on what it could earn at other occupations, taking into account all the other acompanying circumstances—cost of living, occupational preference, advantage of living in city or country, etc. But that is not the question involved in cost of production analysis for farm organization purposes. The question in such a case is, now that I am farming on this farm, what is my time worth to this crop, in view of the alternative uses to which I might put it while remaining on the farm? The hired-labor basis is thus fallacious for proprietor labor also.

It is apparent from the foregoing that labor should be charged at different rates from day to day according to the uses that are competing. The average charge per day will be much higher for some enterprises than for others. The same is true of horse labor and tractor work. And yet the most usual practice is to charge all crops and livestock enterprises at the same rate. Hired labor is properly charged at what is paid for it; but there is still the task of differentiating the rates for different days and enterprises.

Differentiating cost-rates on land between crops in a rotation is an equally difficult matter. The charge should vary according to the plant-food used, or stored up in the land in the case of legumes; according to the state of tilth in which the land is left; and most important of all, according to the value of the land for other crops which they displace from the same position in the rotation—for example, a second crop of corn in succession in place of oats following one crop of corn. As a matter of fact, the almost uniform practice is to charge all crops on any farm at the same rent per acre unless there are wide differences in the fields on which they are grown.

The foregoing should make it clear that the apparent accuracy of composite unit cost of production figures is specious. Some elements in them, such as the physical input data, and those making use of out-of-

pocket expenses, or rates based on cash-value alternatives, such as working on the road, have scientific validity; but when these are thrown in with as many more which are not on a valid basis, the resulting figures are of little value.

No doubt some of you think that the foregoing is an extreme presentation of the case. The cost of production figures obtained in the past amply prove that it is not. In general those enterprises which fill in more or less vacant places in the seasonal round of farm work, or in the crop rotation, or use family labor, appear to be carried on at small profit or even at a loss. And yet to drop them from the farming scheme would reduce the net farm income. Prices fixed on the basis of average costs, although supposedly leaving half the farmers out in the cold, have usually given figures so high that the market has been flooded.

Furthermore, the statement of the case which I have just made would be acepted by any real economist of standing in the United States or Canada. The practices in use in farm cost accounting work have not been developed by economists. They have been partly borrowed from the commercial cost accountants, who in the beginning were engineers and not economists, and still linger in that tradition; and partly created by men who came into farm management out of agronomy, animal husbandry and horticulture. Men with this technical experience can do highly valuable work on the physical aspects of such problems—the relation of physical inputs to physical outputs. But they are out of their element when the analysis reaches the stage of valuation of the inputs.

If composite unit costs of production were necessary in order to solve any problems in the economics of agricultural production, one of the lines of progress in research in this field would be to develop the technique of valuation of the cost factors. But it is now clear that such data are not needed. The attack above described of going directly to the effect on net income provides as complete an answer to the question of what to produce as can be secured. The farmer having the necessary data for such an analysis can calculate the probable effect on his net income of keeping more cows, or growing more corn and less wheat. Whether he wants to do the extra work or not is another question—which he will have to answer for himself and his family. No cost accountant can do it for him. What the long-time effect will be on his soil, is a question for the soils specialist, not the economist.

That the change here described is really taking place, note the following from the report of the survey above mentioned made by the Advisory Committee on Research in Agricultural Economics and Rural Sociology:

"The studies dealing with the farm business and its operation had two rather distinct objectives. The first of these was to determine the kinds of farm organization and the farm practices that would prove the most profitable and to secure data which could be used in formulating suggestions for the improvement of the agriculture of the region. The other group of objectives dealt with the determination of costs of production. The projects having the latter objectives were designed to secure cost of

production and in this way to aid in formulating suggestions for the reduction of cost and to increase profits. The essential difference between the two viewpoints is illustrated in the presentation of the material. The first viewpoint results in the presentation of material in terms of the entire farm business, and the result is measured in terms of the net return to the farm. The second viewpoint results in cost figures showing the cost per acre or per physical unit of product and by comparing this with the price, the computed net profit can be determined. From a study of the reports on these projcts it would seem that the first viewpoint is now more prevalent than the second. The assumption in the first instance is that the farm is the essential unit to be considered while in the second emphasis is placed upon the individual enterprises within the business."

Before the subject of cost analysis is dropped, it also needs to be explained that increasingly the effect on net income is becoming the test of the advantage of different farm practices, such as substituting tractors for horses. It is not possible to ascertain the real advantage of such a change in terms of two comparable cost figures any more than for two farm products. The fewer horses, the less oats to be grown for them. What will be done with the oats if they are grown, or with the corn or barley that may be grown instead? Changes in the rate of feeding beef steers may affect the whole farm economy. Hence, although careful analysis of such things as effect of variations in input upon costs needs to be made, the final form which the results must take is a comparison of operating statements for the whole farm business under different assumptions of input.

I would not want to leave the impression that the great volume of research in the United States centering around cost of production has been valueless. There has accompanied it as a necessary part of it the collection of a vast amount of factual information about farm practices, farm setups, distribution of labor and conflicts between enterprises, that has been highly valuable in the classroom and in extension work. This by-product has been worth more than the main product. Moreover, having this factual information, sensible persons everywhere have been able to forget their carefully elaborated unit costs and profits and reason to sound conclusions along the lines above outlined, which, after all, are those of the practicing farmer.

It will not take long to recount the history of the farm management survey. The first one included 749 farms in Tompkins County, New York, and was made in 1905 by Cornell University. The Office of Farm Management made its first survey in Chester County, Pennsylvania, in 1911. The 1925 Yearbook of the U. S. Department of Agriculture gives a complete list of 71,515 farm records taken in 435 localities between 1904 and 1924. The movement probably reached its apex before 1918. Not only has there been a decline since, but the nature of the survey and its objectives has been changed greatly. The difference is well illustrated by comparing the original Chester County survey with the re-survey reported in U.S.D.A. Bulletin No. 1400, "Factors Affecting Farmers' Earnings in

Southeastern Pennsylvania" by M. J. B. Ezekiel. The old farm management survey had become stereotyped. It collected a set of data looking forward to the calculation of a figure called "labor income", which was set up as a measure of success in farming, along with a group of other "efficiency factors". The analysis itself became stereotyped. The concept of labor income is now recognized to have somewhat limited usefulness, and the other efficiency factors with which to measure the composite effect of several influences, often conflicting. Thus "crop acres per horse" represents the composite effect of more efficient use of horse labor and more intensive working of crops, two opposing elements. Better statistical technique has broken down much of the former analytical procedure.* Surveys as conducted at present are likely to be more limited in objectives and to include enough detail on any one question to permit a sufficiently close analysis of it to furnish a really conclusive answer. The statistical analysis of the data is constantly more rigorous.

The farm management survey, like the cost of production survey, served the very important use in its time of furnishing an excellent description of farming in various regions. Information of this sort was badly needed by teachers and research workers in farm management in the early days; and it is still needed for many areas by many teachers and research workers.

One must not confuse the survey as a method of collecting data with the survey in the special sense used just above of a type of farm management analysis. As the technique of survey taking is improved, this method of collecting data is being more widely used. Of 110 projects exclusively in farm management covered in the above-mentioned survey of research, 59 were collecting all or most of their data by surveys. This method is being freely used in the newer types of marketing organization studies, and in land tenure, credit and taxation studies.

If you ask me the lines which production economics research is taking as it is shifting from cost of production analysis, you can be answered by listing the titles of some of the recent bulletins published by the Division of Farm Management in the Bureau of Agricultural Economics in cooperation with the States. Here are some of the significant titles:

"Practices Responsible for Variations in Physical Requirements and Economic Costs of Milk Production on Wisconsin Dairy Farms"—by M. J. B. Ezekiel, P. E. McNall and F. B. Morrison.

"Causes of Profits or Loss on Virginia Tobacco Farms"—by J. J. Vernon and M. J. B. Ezekiel.

"Types of Farming in North Dakota"—by F. F. Elliott, J. W. Tapp and Rex E. Willard.

"The Combined Harvester-Thresher in the Great Plains"—by Reynoldson, Kifer, Martin and Humphries.

"Profitable Farm Organizations for the Coastal Plain of North Carolina"—by Forster, Saville and Hutson.

*See U.S.D.A. Department Circular 307 "Method of Testing Farm Management and Cost of Production Data for Validity of Conclusions" by Tolley and Mendum. Also the Iowa bulletin by C. C. Taylor and E. B. Hurd, entitled, "Farm Organization and Farm Profits in Tama County, Iowa." These two represent only a small part of the testing that such analysis has received.

"The Peach Situation in the Southeastern States"—by M. R. Cooper and J. M. Park.

Not one of these studies represents conventional analysis along cost of production or farm business survey lines.

The most significant developments in agricultural economics research outside of production are in the field of prices. I did not want to follow up this line of research with you because I have already described it in a paper before the American Farm Economics Association, which you will find published in the April number of the *Journal of Farm Economics*. The statistical attack in this field is mostly directed at analyzing movements of prices in time series, whereas in production economics it is to analyze variations in a cross-section. The price studies have been directed principally at explaining movements in demand, movements in supply, and movements in prices themselves. The relation of prices to both demand and subsequent supply have been explored for a number of farm products on the basis of the data now available. The program of forecasting prices on the basis of these analyses has met with some reverse. No doubt it has been somewhat premature. One can confidently predict, however, that this price analysis will presently do much to help make orderly marketing programs more workable.

Marketing research has been split into two main lines, market prices, already mentioned, and marketing organization. The approach in this latter field is becoming more and more like that in farm organization. The effort is to discover the economic set-up of marketing business units and the business practices that result in the most efficient marketing service. Part of the analysis is in terms of the internal problems of a single unit, and some in terms of integration—the separation and combination of functions or between different units in the marketing chain.

One of the most helpful recent developments in agricultural economics in the United States is its broadening out. The survey classified the 350 projects in force as follows:

Farm Management	125
Marketing and Cooperation	112
Prices	31
Land Economics	21
Taxation	19
Credit	12
Commodity studies	12
Agricultural Geography	9
Agricultural History	4
Income	3
Transportation and Roads	2
	350

The focal point of a large portion of the research at present is the agricultural outlook. Studies are being projected with the view to providing facts and analysis that will aid in the preparation of national, regional

and state outlook statements. Congress has just appropriated $68,000 additional funds for this work. It involves mostly the research in production and prices.

The needs of research in this field are first, for more well trained men. The survey showed of the 288 workers, 8 had no degree of any kind, 59 only a bachelor's degree, 166 a master's degree, and only 55 had a doctor's degree. More significant than this, the majority of the men had taken training in the institutions where they are now doing their work. This means in the majority of cases that it has been a very limited sort of training. Few of these institutions have their training in economics and statistics on a graduate plane. It also means inbreeding — which is one of the greatest weaknesses in the present institution. Of the 100 applicants for the new fellowships in agricultural economics and rural sociology, 76 specified 5 institutions as their first choice, and these same 5 institutions were second choice for 45 of them. These institutions in order, considering first and second choice, are—Harvard, Minnesota, Cornell, Wisconsin and Chicago. Of the 18 appointees, 5 will study at Harvard, 4 at Minnesota, 4 at Wisconsin, 1 at Cornell, and 2 at Chicago. The other institutions are Columbia and Berlin.

The training which these men need most is that which they do not get properly in agricultural colleges, namely in economic theory, which will furnish them with the qualitative background for their work, and in statistics. In statistics they need the theory of it more than the technique. A high school student can be taught to figure correlation coefficients, even of the multiple and partial variety. Large numbers of young research workers have learned the mechanics of correlation. What they need to learn now is what it means. It is significant that 13 of the 100 applicants for the fellowships specified "economic theory" rather than "agricultural economics" as their major objective in their year's work.

The second great need is a more adequate qualitative analysis of economic problems in the field of agriculture. Two recent books have helped greatly in this respect in the field of production. Marketing is most in need of it at present.

The third need is for more joint research projects with other departments in agricultural colleges so that the economic and the natural science aspects of problems can be brought into the same analysis. Many of the real problems of research are of this nature. The Wisconsin bulletin which I mentioned is an excellent example of this.

The Purnell Act appropriated $20,000 additional to each station in 1925-26, and 10,000 more each year up to $60,000 as the maximum. The debates in favor of the bill were all in terms of support for economic and sociological research; but the act was so phrased as to let the funds be used for other purposes also. Of the first $940,000 made available, 26 per cent was used on agricultural economics projects; of the next $470,000, 34 per cent. But in many institutions more or less state support for research has been withdrawn at the same time. The funds spent in agricultural economic research were $356,000 in 1924-25. They increased the first year of the Purnell Act to $608,000, and the second year to $769,000.

CULTURAL STUDIES OF *BACILLUS LARVAE* (WHITE)

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Introduction

Of the different infectious diseases to which the larva of the honey bee is subject, what is now recognized as American Foulbrood is generally regarded as being the most serious. Although the infectious nature of the foulbrood diseases had been apparent for a long time, it was not until approximately twenty years ago that any clear distinction could be established between them. However, with the discovery in 1907 by White (*10*) of the causal organism in American Foulbrood, much confusion was removed, particularly with respect to the distinction between this disease and that known as European Foulbrood, the etiology of which is still in doubt.

The organism responsible for American Foulbrood, *Bacillus larvae,* is present in practically pure culture in the dead larvae, which decay to a dark brown glue-like mass, ropy at first but later drying to a tough scaly material which adheres to the lower side of the cell. Although the spores of the organism are readily demonstrable in the larval remains (see Pl.I,Fig.1), the establishment of it as the causal factor was delayed by the fact that it does not develop on the ordinary laboratory media for cultivating bacteria. White, however, succeeded in cultivating the organism on a medium containing crushed healthy bee larvae. As prepared at first (*9*) using heat sterilization, the medium permitted of but feeble growth. With a modification of this substrate whereby a broth of macerated larvae, passed through a bacterial filter, is added aseptically to a basic medium of nutrient agar, White (*10*) obtained better growth of the organism, enabling him to conduct inoculation experiments leading to the definite establishment of *B. larvae* as etiological factor. Later the same investigator (*11*) prepared a medium in which egg-yolk, removed aseptically from the shell, was added in place of the bee larvae. On this medium better growth was secured. It was, however, later modified by Sturtevant (*6*), who added aseptically egg-yolk to a basic medium of yeast, peptone and sodium glycerophosphate.

About the time of White's earlier investigations, Maassen (*5*), working independently, succeeded likewise in cultivating the organism associated with this same disease and established the identity of the causal organism which he named *Bacillus brandenburgiensis.* White, however, is generally given credit for priority, and his appellation, *B. larvae*, is that most widely used to indicate the organism. Maassen employed a medium containing crushed brood and also prepared a special substrate composed of a broth of calf or pig brain to which egg albumin, peptone and agar were added.

Of the above media for cultivating *B. larvae,* the usefulness of some is limited due to the difficulty and trouble of their preparation. In the case of those made from bee larvae, the difficulty of obtaining a sufficient supply of brood at certain seasons and the relatively large amount of material required

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render it generally unsuitable. Egg-yolk media, on the other hand, are more easily prepared, and have come into more general use. They have, however, the disadavantage of being opaque, rendering the study of the organism more difficult, not only on solid media where colonies are difficult to recognize, but also in fluid media where clarity of the solution is important if the characteristics of the organism are to be studied to the best advantage.

Experimental Work

The data in the present paper are based on that phase of our investigations with *Bacillus larvae* which deals with a study of the cultivation of the organism on artificial media and with a determination of its outstanding cultural and physiological characteristics. It was felt that a better knowledge of the organism, its morphology, physiology and capability of laboratory cultivation and recognition would contribute to our better knowledge of the disease itself and means to combat and eliminate it.

Partial descriptions of the cultural characteristics of *B. larvae* have been given by White (*12*), Maassen (*5*), Sturtevant (*7*) and Borchert (*1*). It is probable, however, that the inability of the organism to grow on the usual media for studying bacteria has so far prevented a characterization of its properties to a degree approaching that for bacteria in general.

Growth Requirements of *B. larvae*

In devising media upon which *B. larvae* would thrive a large number were tried out containing many ingredients in various combinations. The results of the first experiments in this direction have already been given (*4*) and need only be alluded to at this time.

Using yeast, pollen and brood, both singly and in combination as a base, nitrogenous materials containing nitrogen in different form were added, as nitrate, ammonium salt, amino acid, peptone and egg protein. Egg-yolk was distinctly superior to the other nitrogenous materials, while brood, with or without the addition of yeast, served as the best base of those tried. Pollen, contrary to expectations, seemed to depress growth under the conditions of the experiment.

Using yeast, peptone and glycerophosphate, upon which *B. larvae* will grow to some extent, as a base, 230 modifications were tested with the addition of combinations of various amino acids and proteins. In this series it was found that the amino acids, as a rule, exerted a neutral or depressing effect on the growth of *B. larvae*, while, as before, best results were obtained with modifications containing unheated egg proteins. Those media, however, which gave most abundant growth possessed the disadvantage of opacity, and consequently further experiments were made with the object of obtaining a medium capable of supporting good growth, while being at the same time clear.

Tests with Plant Extracts

As it seemed possible that the superior growth-promoting qualities of egg-yolk media (particularly yeast-egg-yolk) might depend on certain "food accessory substances", further tests were conducted with comparatively simple media containing small amounts of aqueous extracts of orange, tomato and carrot, materials known to be sources of growth-promoting substances for

the higher animals. Extracts were prepared by macerating 100 grams of minced material in 500 c.c. water, filtering and adding 1 c.c. to each 7 c.c. of base in a tube. Additions were made respectively of raw filtered extract, of extract treated with animal charcoal (by which Vitamine B is adsorbed) and with extract subjected to heat (15 lb. steam pressure for 30 min.), the last treatment tending to impair Vitamine C. The results, shown in Table 1, indicated the usefulness of plant extract in the cultivation of *B. larvae,* particularly in the case of the untreated extracts. This was evident with both Base A (without yeast) and Base B (with yeast). In the former case the addition of the plant extract made the difference between no growth whatever and good growth. The media, moreover, had the advantage of being clear, both in solution and in solid form, enabling a better study of the organism and its growth under both conditions. It is of interest to note that under the experimental conditions, the growth-promoting property of all three plant extracts was found to be impaired both by the charcoal and the heat treatment though not completely destroyed.

TABLE 1.—*Effect of plant extracts on growth of B. larvae.*

Nature of plant extract added	Base A peptone and glycero-phosphate	Base B peptone glycero-phosphate and yeast
Check—nothing added	no growth	+
Orange—raw, filtered	+ + +	+ + + +
Orange—treated with animal charcoal	+	+
Orange—heated	+	+ +
Tomato—raw, filtered	+ +	+ + +
Tomato—treated with animal charcoal	+	+
Tomato—heated	+	+ +
Carrot—raw, filtered	+ + +	+ + + +
Carrot—treated with animal charcoal	+ +	+ + +
Carrot—heated	+	+ +

Further tests on the effect of carrot extract indicated that by increasing the concentration of the extract, satisfactory growth could be obtained on media sterilized in the regular way by heat. For subsequent work carrot extract was prepared by macerating 200 grams carrot with 500 c.c. water, filtering and adding in the proportion of 1 volume to 5 volumes of base containing 1% peptone and 0.05% K_2HPO_4. For solid media the usual 1.5% agar was added.

It is interesting to note that the carrot extract, though able to stimulate growth of *B. larvac* when added to the base containing phosphate and peptone, is unable to do so if the latter is omitted. Evidently some source of nitrogen other than may be contained in the extract is required. Nitrate and ammonium nitrogen, however, are unable to take the place of peptone (see Table 2).

The carrot extract, as prepared above, was found to contain approximately 1 per cent reducing sugars which might well be considered as the source of the advantage of the extract. Equivalent amounts of dextrose solution, however, were unable to replace the carrot extract on addition to the phosphate-peptone base. When, however, yeast was present in the base the addition of equivalent amounts of dextrose solution noticeably stimulated

TABLE 2. *Growth of B. larvae in relation to composition of medium.*

Composition of medium in addition to K_2HPO_4 0.05%	Growth
Carrot + peptone	+ + +
Carrot + KNO_3	—
Carrot + $(NH_4)_2SO_4$	—
Carrot	—
Peptone	—
Peptone + dextrose	—
Carrot + peptone + yeast	+ + + +
Peptone + yeast	+ +
Peptone + yeast + dextrose	+ + +

growth of *B. larvae* particularly on solid media. In considering the beneficial effects of such substances as yeast, egg-yolk, carrot extract on bacterial growth one can only conjecture as yet concerning any possible vitamine effect. Recently Uyei (*7*) found that substances rich in vitamine B, including orange, tomato and cabbage juice, exerted a stimulating effect on the growth of tubercle bacilli, while Kulp (*3*), in reporting satisfactory cultivation of *L. acidophilus* and *L. bulgaricus* on a medium containing tomato juice and peptone, suggests the action of a possible "accessory substance or substances." As with our results with carrot, there was evidently present in tomato juice, acording to the last named author, some other factor in addition to the carbohydrate which stimulated the growth of the organisms. However, as Werkman (*8*) indicates, there is great need for caution in distinguishing between a purely nutritive effect and a vitamine effect, the author pointing out the advisability of restricting the meaning of the term vitamine to those substances not carbohydrates, proteins, fats and minerals essential to the growth and reproduction of suitable animals. It cannot as yet be justifiably extended to include substances stimulating the growth or reproduction of microörganisms.

YEAST-CARROT MEDIUM FOR *B. larvae*

It was found that the addition of yeast to the peptone-phosphate base induced better growth of *B. larvae,* particularly on solid media. Consequently yeast-carrot agar and broth were finally adopted as standard media for cultivating this organism.

Preparation of medium—The base is prepared by adding to 1000 c.c. distilled water, 10 gram peptone, 0.5 gram K_2HPO_4 and 10 gram pressed yeast. The mixture is heated in a double boiler and then boiled over the flame, with stirring, for 5 to 10 minutes. It is then filtered through a Buchner funnel, first through paper alone, finally using infusorial earth to clarify. To the filtrate 1.5% agar is added for solid medium and dissolved by boiling or autoclaving as usual. To the base is added carrot extract prepared by mincing 200 gram cleaned carrots and macerating in a mortar with 500 c.c. distilled water. After allowing to stand for 15-30 minutes the carrot mixture is passed through cheesecloth, squeezing to collect as much liquid as possible. The liquid is then filtered through paper and finally cleared with infusorial earth as with the yeast solution. The carrot solution as prepared above

should be a clear, faintly greenish solution with a pH value of approximately 6.5. It is added to the base in the proportion of 1 part extract to 5 parts by volume of yeast-peptone base. The medium is tubed and sterilized in the usual manner, no adjusting of the reaction being required. Both liquid and solid media are clear and permit of ready observation of the type of growth of *B. larvae*.

Cultural Characteristics of *B. larvae*.

As already intimated, B.larvae does not grow on the usual media; indeed absence of growth on nutrient agar inoculated from foulbrood material constitutes one of the confirmatory tests in diagnosing the disease. The usual media employed in the regular determination of the various properties of bacteria are therefore out of the question. It was found, however, that by adding carrot extract practically all of these various media could be made to support growth of *B. larvae* which, though not as abundant as with yeast-carrot media, was sufficient to make possible a study of the physiological characteristics of the organism. When used, 20 per cent carrot extract prepared as previously described was added to the medium in question.

Yeast-carrot agar—In surface streak cultures there is good growth in 24 hours at 37°C. along line of inoculation, though maximum development is not usually obtained until 48 hours. The growth is grayish-white with ground glass appearance, slightly raised with little tendency to spread; edge slightly lobate; growth somewhat viscid. Plate I, Fig. 2 shows 24 hours growth of *B.larvae* on yeast-carrot agar, inoculated with a loopful of suspension. Older cultures tend to become brownish, and in general, more transparent.

Colonies on this medium are small, whitish, somewhat transparent, smooth, and slightly glistening. They are generally round, a few mm. in diameter, with somewhat lobate margin. Viewed with the microscope they are seen to be granular with characteristic irregular edges consisting of interwoven thread-like masses usually much curved and extending like a fringe from the colony. In Plate I, Figs. 3 and 4 are shown young colonies.

Yeast-carrot broth—Good growth in 24 hours at 37°C. occurring in the body of the medium, none at the top. The growth is fungoid in appearance, resembling masses of loose cotton wool floating in a clear liquid. This type of growth is characteristic of *B. larvae* in liquid media and is doubtless connected with the morphological changes in the organism, the rod form of solid cultures giving place to a filamentous form in young liquid cultures. The fungoid masses are easily broken up on shaking, the culture then assuming a uniform cloudiness. In older cultures the growth may sink and lose some of its flocculent character. There is a development of acidity in this medium due to the fermentation of the sugars of the carrot extract, the maximum acidity reached being approximately pH—5.5.

Nutrient agar—With inoculations as ordinarily made, no growth. In the case of exceptionally heavy inoculations, there may be some very slight indication of development in 1 to 2 days, which does not progress. Further transfers are in all cases sterile. With addition of carrot extract there is noticeable growth along line of inoculation, less abundant and much more transparent than on yeast-carrot agar; otherwise, on this, and on other solid media containing carrot, the type of growth is essentially the same.

Nutrient broth—No growth observed. On the addition of carrot extract there is moderate, fungoid growth after 1 to 2 days, which sinks later forming a viscid sediment. The reaction, as in all media containing carrot, becomes acid.

Gelatine—No growth at temperatures at which gelatine remains solid. At 37°, however, there is evidence of some variability in the behaviour of different strains of *B. larvae* towards gelatine. Sturtevant (*6*) noticed with some strains slight growth with some softening of the gelatine, without, however, sufficient liquefaction to denote a definitely positive action. Maassen on the other hand noted a gradual, though definite, liquefaction of gelatine, on which the organism was found to grow slowly. By the addition of 1 per cent dextrose growth was much improved, liquefaction also occurring in the presence of the sugar. With our cultures in plain gelatine in but two cases out of ten was there sign of softening of the gelatine after six weeks at 37°, with little or no visible evidence of growth. In carrot gelatine, however, there was a flocculent growth at the bottom of the tube while in the case of four strains there was evidence of liquefaction after six weeks.

Milk—In plain milk a very slight acidity is produced with curdling in 1 to 2 weeks at 37°C. The curd is more of the rennet than the acid type. With the addition of carrot extract slightly more acidity is noticed, and curdling takes place sooner, generally within 3 days, followed by some extrusion of whey. After 6 weeks, however, there is no definite peptonization observed.

Potato—No growth has been observed.

Carbohydrate fermentation—No growth in the ordinary sugar broths. The addition of carrot extract not being feasible owing to the presence of sugars, a base of yeast extract and peptone was prepared to which the carbohydrates to be tested were added. No gas was observed with any of the carbohydrates tested. Definite acidity was produced in dextrose, levulose, galactose, salicin and xylose. With lactose and saccharose slight acidity was produced by some strains. No acidity was noted with mannite or dulcite.

Diastatic action—On ordinary starch agar no growth of *B. larvae* was observed. The organism grew moderately well on starch carrot agar, showing a whiteish, transparent, flat and smooth growth. With none of our strains was there any indication of starch hydrolysis.

Indol fermentation—None observed after 3 weeks in peptone-carrot broth, in yeast-carrot broth, in yeast-peptone broth or in yeast-egg-yolk broth, using the Ehrlich-Böhme test.

Hydrogen sulphide production—No growth of *B. larvae* in plain lead acetate agar. In lead acetate-carrot agar there is moderate, uniform growth along the line of puncture in the form of narrow veil-like folds extending a short distance into the medium. There is a blackening of the growth accompanied by a darkening of the adjacent medium. It is characteristic, however, that the blackening occurs only in the lower half of the stab.

Ammonia production—*B. larvae* appears to be capable of forming small amounts of ammonia. In none of the cultures tested, however, have more than traces been noticed.

Nitrate reduction—In nitrate broth containing carrot extract a marked nitrite test is obtained due to growth of *B. larvae*. It is worthy of note, however, that nitrites can be readily detected in yeast-carrot broth or agar cultures without further addition of nitrate, under conditions where all nitrate-reducing bacteria so far tested have failed to give a nitrite reaction. There is evidence that this peculiar property may become of diagnostic value in the detection of *B. larvae*. Nitrite formation by this organism is being made the subject of special study.

Effect of reaction of medium—growth of *B. larvae* was found to occur, though not with all strains tested, between pH = 5.5 and 8.0. The optimum hydrogen ion concentration, however, was found to lie between pH = 6.5 and 7.0. The pH of uncapped normal bee larvae has been reported by Sturtevant (l. c.) and Fabian and Parks (*2*) to be 6.8 and 6.6 respectively. The last named authors report the optimum pH for *B. larvae* to lie between 6.6 and 7.0.

Relation to temperature.—No growth of *B. larvae* has been observed by us at room temperature. The organism develops fairly well at 30°C. finding its optimum about 37°. At 45°C. there is little or no growth.

Relation to oxygen.—The organism is a facultative anaerob, growing much less abundantly with complete absence of oxygen. Under conditions of partial anaerobiosis it grows well.

Note on Morphology.

Bacillus larvae is an organism which exhibits pronounced pleomorphism, showing indications of a life-cycle embracing a variety of cell-types as well as apparently amorphous stages concerning which studies are under way. The dimensions of the organism on brood agar have been given by both Maassen (*5*) and White (*12*), the former reporting it 2.5—5 μ in length and 0.7—0.8 μ in width, the latter 2.5—5 μ long and 0.5 μ wide. In young cultures on this substrate it is typically a slender rod, sluggishly motile, with a tendency to grow in chains. On yeast egg-yolk agar the rods tend to lengthen (see Pl. I, Fig. 5), while on yeast-carrot agar the cells present a different appearance, being noticeably shorter, usually somewhat curved, and with less tendency to chain formation (see Pl. I, Fig. 6). This marked variability in size and form further illustrates the importance of referring all descriptions of bacteria and their measurements to culture medium, age of culture and environmental conditions.

When cultivated in liquid media, *B. larvae* has a tendency towards formation of filaments (see Pl. II, Fig. 1), which in old cultures may become very long, twisted and of varying thickness. We have also been able to corroborate White's findings concerning the appearance of coccoid forms in older cultures, which forms result apparently from a disintegration of the rods (see Pl. II, Fig. 2). Young rods and filaments stain by Gram's method but as cultures get older an increasing proportion of the cells appear Gram negative. Spores are formed rarely on the media we have employed, particularly in the presence of sugars. They may be produced, however, on yeast-peptone agar, without sugar. Sporangia are spindle shaped (see Pl. II, Fig. 3), the endospores arising, as mentioned by Maassen, towards one

end of the spindle. Other development stages are seen in Plate II, Fig. 4, which shows large, irregular, swollen rods, branching forms, and what is apparently conjugation with zygospore formation. This latter process, however, has been noticed quite clearly in carrot-yeast broth cultures.

Considerable work still remains to be done concerning the significance of the different morphological stages of *B. larvae* and their relation to the life-cycle of the organism. There is reason to believe that further light in this direction would aid, as it should in the case of pathogenic organisms in general, in a better understanding of epidemiological problems.

Summary.

1. Growth requirements of *B. larvae* (White) have been considered in experiments designed to study suitable media for the cultivation of this organism which does not develop on ordinary laboratory media.
2. Plant extracts have been found useful in cultivating *B. larvae* and a transparent medium containing carrot extract in addition to peptone and yeast, has been found to give satisfactory development of the organism.
3. The general cultural characteristics of *B. larvae* are described.
4. *B. larvae* exhibits pronounced variability in morphology according to the medium and cultural conditions.

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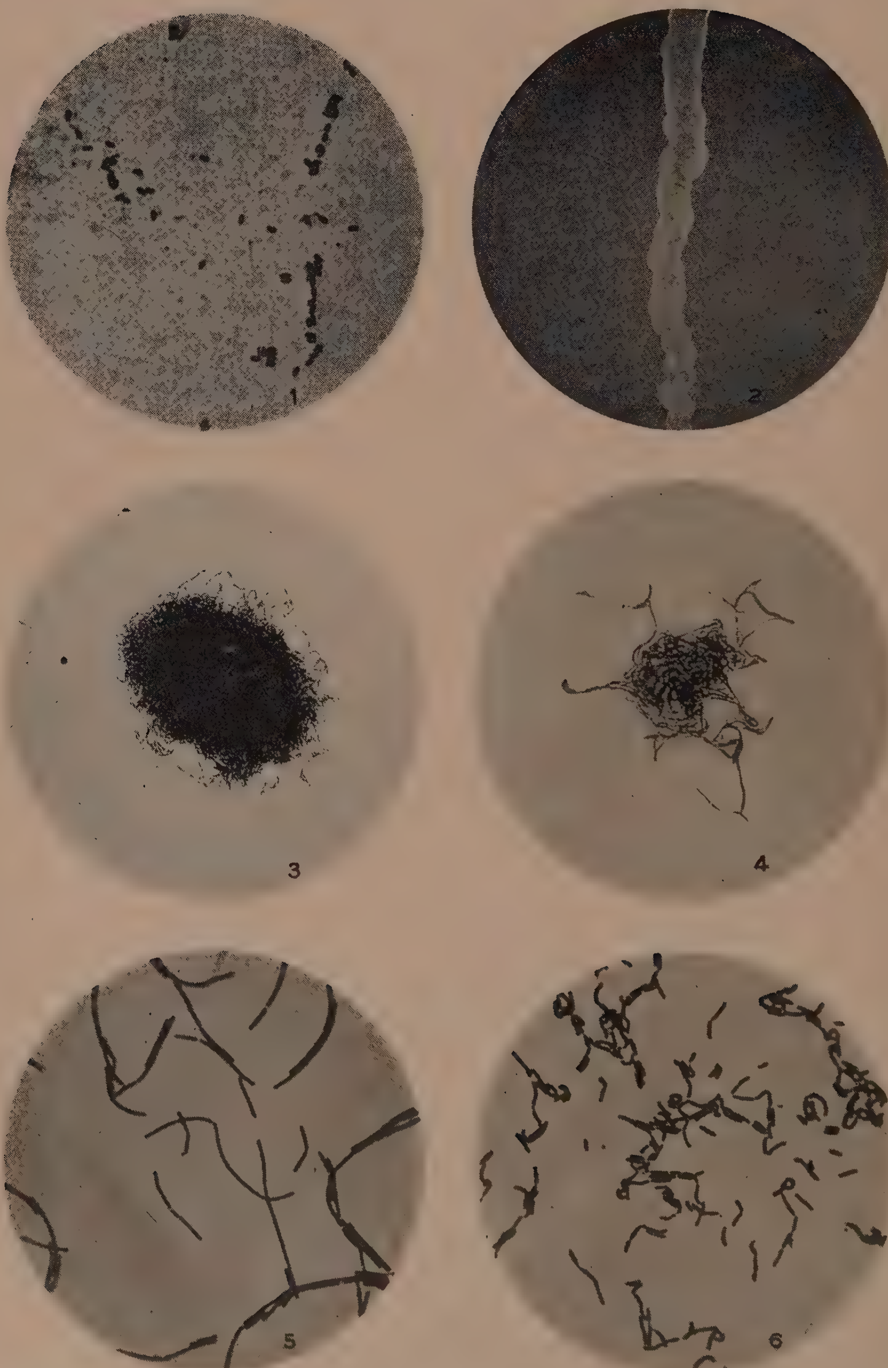

PLATE I.

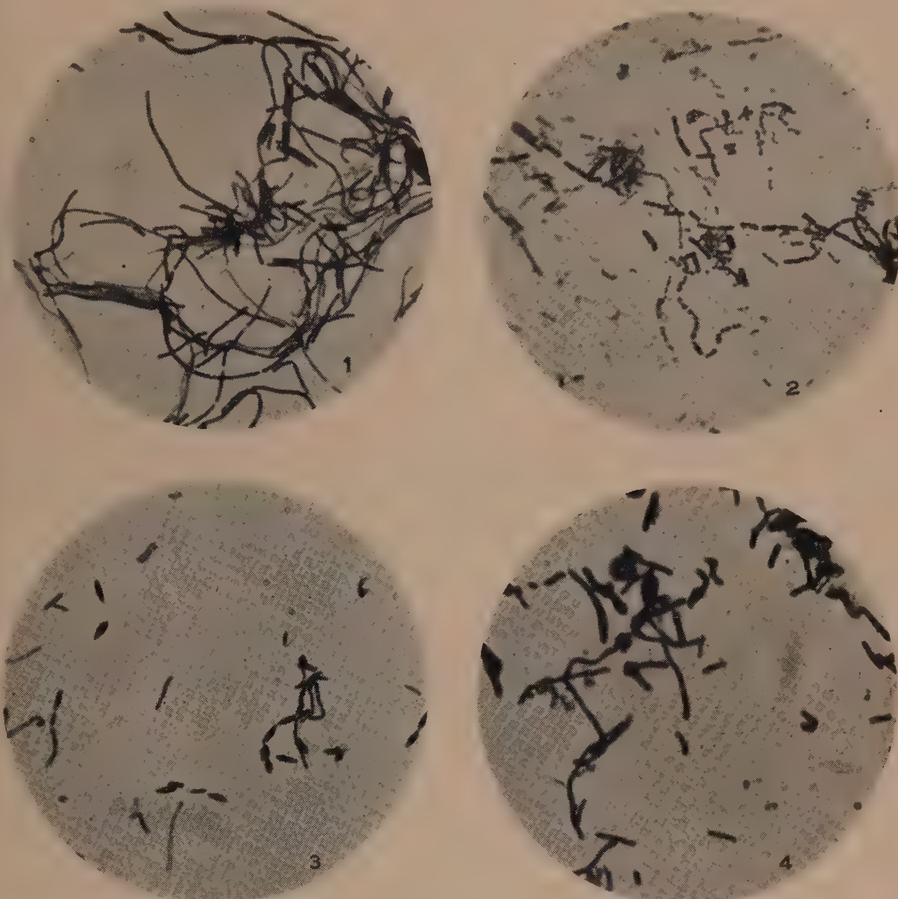

PLATE II.

EXPLANATION OF PLATES

PLATE I.

FIG. 1. *B. larvae.* Spores from comb of American Foulbrood. Carbol-fuchsin. x 1000.

FIG. 2. Streak culture of *B. larvae* on yeast-carrot agar, 24 hours at 37°C., very slightly enlarged. x 1.2.

FIG. 3. Young colony of *B. larvae* on yeast-carrot agar. Impression preparation, stained with fuchsin. x 100.

FIG. 4. Young colony of *B. larvae* on yeast-carrot agar. Impression preparation, stained with fuchsin. x 250.

FIG. 5. *B. larvae* from 24-hour culture on yeast-egg-yolk agar at 37°C. Long vegetative rods and chains. Gram's stain. x 1000.

FIG. 6. *B. larvae* from 24-hour culture on yeast-carrot agar at 37°C. Short curved rods. Gram's stain. x 1000.

PLATE II.

FIG. 1. *B. larvae* from 24-hour culture on yeast-carrot broth at 37°C. Filamentous forms. Gram's stain. x 1000.

FIG. 2. *B. larvae* from 9-week culture in yeast-peptone broth. Rods disintegrating with formation of coccoid bodies. Fixed in formalin, stained with carbol-fuchsin. x 1000.

FIG. 3. *B. larvae* from 2-day culture in lead-acetate-carrot agar, stab inoculation, spindle shaped sporangia. Gram's stain. x 1000.

FIG. 4. *B. larvae* from 8-day culture in lead-acetate-carrot agar, stab inoculation, 37°C. Showing large irregular, swollen forms, branching and conjugating rods. x 1000.

THE FIRST YEAR EGG PRODUCTION OF BARRED PLYMOUTH ROCKS

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Studies based on production records covering the first laying year for S. C. White Leghorns and S. C. Rhode Island Reds bred at the University of British Columbia have been previously (*2, 3*) reported. The present study is based on similar data for Barred Plymouth Rocks.

At present comparatively little data are available on normal first year egg production of pullets under the environmental conditions prevailing in what is usually referred to as the Pacific North West. Such data are required alike by the breeder and the investigator since both need to know what rate of egg production should be considered 'normal'. It is the object of this paper to present records for a flock of Barred Plymouth Rocks whose egg production may be considered typical for flocks of the breed that have been bred for egg production and are kept under similar environmental conditions.

Review of Literature

The history of the Barred Plymouth Rock is intimately associated with the history of poultry breeding in America. The barred variety was described in the first "Standard of Excellence" published by the American Poultry Association in 1874 and was, until 1888 (*1*), the only recognized variety of the breed. This variety apparently gained a leadership in popular esteem at that time which it has maintained up to the present time, at least so far as the heavier breeds are concerned. The popularity of the variety in Canada is indicated by the large number of birds of this variety entered in official Canadian contests, the number of Barred Rocks in the first eight contests representing 35.8 per cent of all birds entered. This popularity is, however, more marked in other parts of Canada than in the Province of British Columbia where the Leghorn holds the dominant position.

The Barred Plymouth Rock has the distinction of being the first variety of any breed of which we have any record to be systematically selected for egg production with the aid of trapnests. The selection work referred to was started by Professor Gowell in 1899 and was later continued by Dr. Pearl and his co-workers at the Maine Station. The data for the first eight years were published by Pearl and Surface (*9*) who found that the 'average absolute weighted mean egg production' for the period from November 1st to October 31st of the first laying year was 128.86 eggs.

Since the report by Pearl and Surface (*9*) was published, considerable data on first year egg production of Barred Plymouth Rocks have accumulated from egg laying contests and elsewhere. The latest and most complete report is that given by Dunn (*6*) for birds entered in the contest at Storrs, Connecticut. In the years 1911-1919 the average first year egg production of the 655 Barred Plymouth Rocks in the Storrs Contest (*6*) was 163.05

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eggs. This is an increase of nearly three dozen (34.19) eggs over the average reported by Pearl and Surface but corresponds closely to that estimated by Pearl (*10*) for the Maine Station Barred Rocks in 1913-14.

The report issued by Dryden (*5*) on the breeding work at the Oregon Agricultural College is of special interest, since the foundation stock in Barred Plymouth Rocks for the University of British Columbia came from that institution. Dryden started with a flock of 92 birds in 1908-09 which finished their first laying year with an average of 82.67 eggs each. By 1910-11 the average egg production had increased to 161.78 eggs and in 1917-18, the last year reported, the average for 62 pullets was 202.40 eggs each. These averages, it should be noted, are based on the first 365 days rather than on eggs laid from November 1st to October 31st as in the case of other records cited.

It will be noted from the brief references made to some of the reports published on egg production of Barred Plymouth Rocks that an average production of slightly over 160 eggs has been obtained on the Eastern part of the North American continent, while the only report issued from or near the Pacific Coast shows that the average attained was approximately 200 eggs.

Materials and Methods

This study is based on first year (Nov. 1st. to Oct. 31st.) trapnest records of 569 Barred Plymouth Rock pullets hatched, reared and trapnested on the poultry plant of the University of British Columbia. Eggs laid outside of trapnests, which numbered approximately one egg per bird, were not included.

Time of hatching, selection, housing, feeding, etc., were the same as previously outlined (*2, 3*).

The mean, standard deviation and coefficient of variation were calculated by the usual formulae as outlined by Babcock and Clausen (*4*) and others. The records for monthly egg production were grouped in one-egg classes, so as to give the correct value to zero records. Annual egg production was calculated from grouped data, using a class range of 15 eggs (0-14 etc.) The range in monthly and annual egg production was from 0 to 31 and 48 to 296 eggs respectively. All computations were checked to eliminate errors as far as possible.

Annual Egg Production

The data for annual egg production are shown in Table 1. The Table shows that the number of birds which completed the year was fairly constant, ranging from 92 birds in 1923-24 to 100 birds in 1921-22. From 100 to 115 birds were banded each year and of these from 6 to 15 or from 5.9 to 13.0 per cent died. Altogether 625 birds were banded of which 56 or 9.0 per cent died.

The average first year production ranged from 187 eggs in the first year to 211.47 eggs in 1924-25. If the first year is compared with the last year, it is found that production has increased by 19.89 ± 4.42 eggs, which is statistically significant. The increases do not occur regularly and gradually but are confined to an increase in the production in 1921-22 over the

TABLE 1.—*Summary of variation constants for annual egg production.*

Year	No. of Birds	Mean	Standard Deviation	Coefficient of Variation
1920–21	93	187.00±2.94	41.97±2.08	22.44±1.16
1921–22	100	195.10±2.47	36.58±1.74	18.75±0.93
1922–23	94	193.07±2.75	39.46±1.94	20.44±1.06
1923–24	92	194.34±2.43	34.51±1.72	17.76±0.91
1924–25	95	211.47±2.63	37.98±1.86	17.96±0.91
1925–26	95	206.89±3.30	47.75±2.34	23.08±1.19
All Years	569	198.02±1.15	40.80±0.82	20.60±0.42

preceding year, which increase was maintained in the two subsequent years. Another increase occurs in 1924-25 with a slight decrease in the following year.

There is comparatively little difference in the absolute variability as measured by the standard deviation from the first to the last year. The standard deviation is higher for the first and for the last year than for the intervening years. As measured by the standard deviation, the production for 1923-24 was least variable, while that for 1925-26 was most variable. It does not appear from the data that there has been any marked change, however, during the period of six years.

The coefficient of variation is only very slightly greater for the last than for the first year. The differences here can scarcely be considered significant, although the relative variability (coefficient of variation) in 1923-24 was appreciably less than for 1925-26.

It is of interest in connection with Table 1 to compare the figures here presented with those from other sources. The average production of 198 eggs is comparable to that reported by Dryden (*5*) and, like the production obtained in Oregon, is considerably higher than that reported by Dunn (*6*) for Barred Plymouth Rocks entered in the Storrs Contest. The standard deviation for our Barred Rocks is practically the same as that reported for birds in the Storrs Contest, while the coefficient of variation is lower, indicating that the production of the birds whose records are reported in this paper was relatively less variable.

In view of the differences between the production reported in this paper and those from other sources, it seemed desirable to follow the procedure adopted in a previous paper (*3*) and compare the production of this flock with that of birds entered in contests in British Columbia and other parts of Canada. The results of the statistical analysis of some of the contest data are shown in Table 2. To represent the production of birds entered in contests outside of British Columbia, the records of all birds entered in the first five 'Canadian' contests at Ottawa were used. Only the records of birds which were shown to have completed the first laying year as reported by Elford and Taylor (*7*) were used. It will be seen that the 957 birds which completed their first year records in the 'Canadian' contests laid 165 eggs each, which is very close to the production reported for birds in the Storrs Contest. The 148 Barred Rocks entered during the corresponding period in British Columbia contests laid on the average 193 eggs which is comparable to the records reported for the birds studied in this paper and by Dryden. It is interesting in this connection to note that, if the records made by Barred Rocks in British Columbia

TABLE 2.—*Annual egg production of Barred Plymouth Rocks in the "Canadian" and British Columbia contests.*

Source of Records	No. of Birds	Mean	Standard Deviation	Coefficient of Variation
Canadian Contest 1919–20 to 1923–24	957	165.29±1.07	49.01±0.76	29.65±0.50
B.C. Contests only 1920–21 to 1923–24	148	192.78±2.70	48.65±1.91	25.28±1.05
B.C. Contests only 1920–21 to 1925–26	302	198.32±1.85	47.72±1.31	24.06±0.70

contests during the following two years (1924-25 and 1925-26) are included, the average production is raised to 198.32 eggs, which differs by only a fraction of an egg from the average production of the 569 birds whose records are shown in Table 1. It is also interesting to note that the absolute variability (standard deviation) is approximately the same for the three groups shown in Table 2, with the result that the coefficient of variation tends to be slightly lower for the birds entered in British Columbia contests.

As with the records for Rhode Island Reds quoted in a previous paper, the contest data for British Columbia closely approximate those of the flock studied but differ from records made in contests in other parts of Canada. This raises an important question with regard to whether the factors responsible are inherited, environmental or both. The data presented do not furnish an answer to this question. They merely show what has long been recognized, that certain differences in egg production do exist (see Table 2).

Proportion of High Producers

As noted before the average production has increased by approximately 20 eggs. This increase is reflected in the proportion of high and low producing birds which is shown for the different years and for all years in Table 3. For reasons which have been previously set forth the classification used in preparing this Table corresponds to that used in Canadian Record of Performance. The classification adopted by Dunn (*6*) is not applicable to the flock studied in this paper, since only 14 birds or 2.46 per cent of the 569 birds laid 104 or fewer eggs, whereas 224 or 39.37 per cent of them laid 210 or more eggs.

Table 3 shows that the majority, or 65.0 per cent of the birds, when the records for all years are considered together, were in the intermediate group of birds which laid from 150 to 224 eggs each. Those laying 225 or more eggs comprise the next largest group (25.0 per cent) while those that laid less than 15C eggs form the smallest group with only 10.0 per cent of the entire flock.

TABLE 3.—*Relative frequency of hens in different fecundity classes.*

Year	Per cent laying 149 eggs and less	Per cent laying 150 to 224 eggs	Per cent laying 225 eggs and more
1920–21	21.5	62.4	16.1
1921–22	5.0	76.0	19.0
1922–23	10.6	64.9	24.5
1923–24	7.6	71.7	20.7
1924–25	4.2	58.9	36.8
1925–26	11.6	55.8	32.6
All Years	10.0	65.0	25.0

The number of individuals in the group of comparatively high producing birds which laid 225 or more eggs changed more consistently than did the number of birds in the other two groups. This is shown in Table 3 and is further illustrated in Figure 1. The equation for the straight line in Figure 1 is $y = 15.509 + 3.778x$. It is also interesting to note that the changes in the percentage of birds in this group, which varied from 16.1 to 36.8 per cent, follow the changes in average first year egg production (Table 1).

The proportion of birds in the intermediate group, which varied from 55.8 to 76.0 per cent, decreased slightly. This is illustrated by the upper lines in Figure 2. The equation for the straight line for this group is $y = 70.470 - 2.206x$. The comparatively low producing birds with records of 149 eggs or less comprised 21.5 per cent of the flock the first year (1920-21) but in subsequent years varied from 5 to 11.6 per cent. The tendency to decrease in the proportion of birds in this group indicated by the lower straight line in Figure 2 is due to the comparatively large numbers in this group in 1920-21. The equation for this line is $y = 14.021 - 1.572x$. In the case of this flock of Barred Rocks there has been an increase in the proportion of high producing birds with a corresponding decrease in the lower producing birds without, however, eliminating the lowest producers.

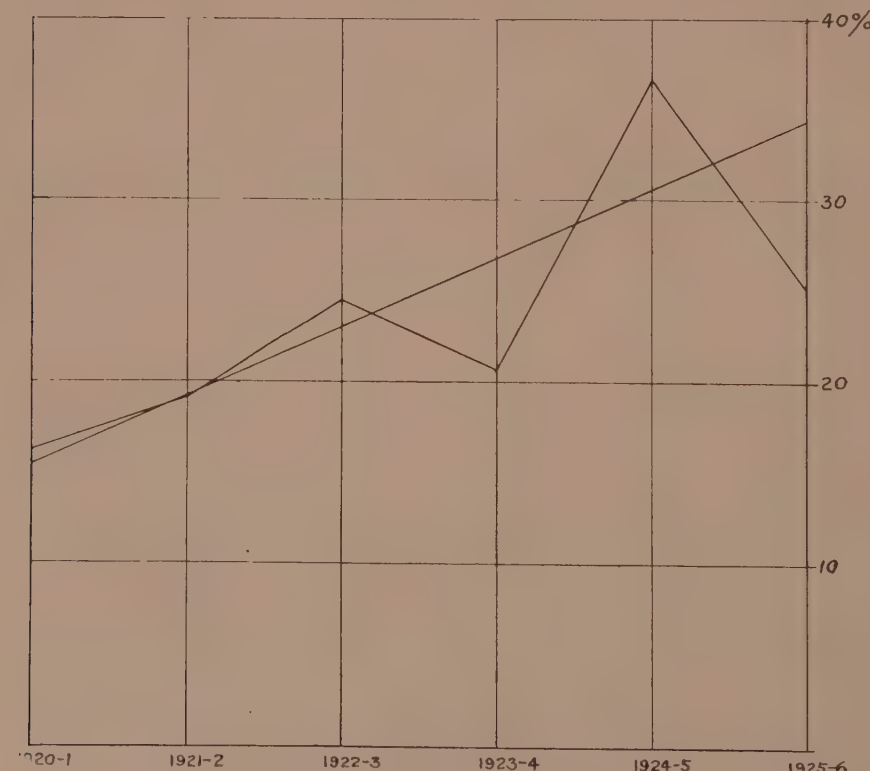

FIGURE 1. Annual changes in the percentage of pullets laying 225 or more eggs in their first year. (Charts drawn by Mr. G. Sinclair Smith).

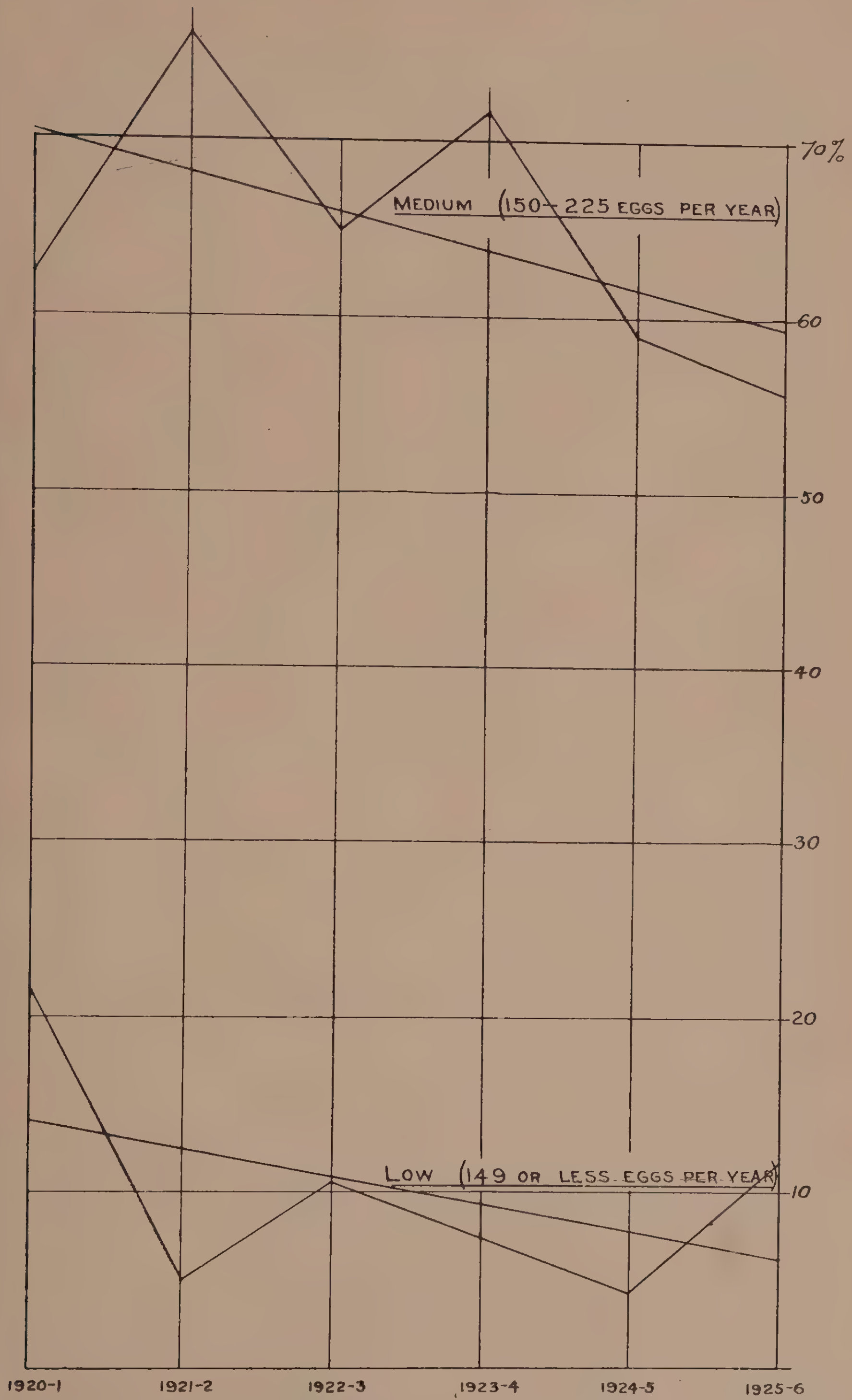

FIGURE 2. Annual changes in the percentage of pullets laying 150 to 224 eggs and pullets laying 149 or fewer eggs.

Distribution of Egg Production by Months

The distribution of egg production in the different months of the year for the birds hatched in 1920 and 1925 and the combined records for all birds is given in Table 4. The data presented in this table are also shown in Figure 3 which shows the distribution of eggs laid in the first and last years and the average for all birds.

Considering first the figures based on all birds studied, it will be seen that the winter egg production is considerably below that of the spring and summer months. The number of eggs laid during the winter months ranges from 7.28 eggs in November to 14.74 eggs in January. The production for the months of December, January and February remains fairly constant. There is a distinct increase in March over the production in February, with a further increase to 23.7 eggs in April. After April, production declines gradually until September when the average is 16.14 eggs.

The October production of 10.23 eggs is distinctly lower than the production in preceding months, due partly to the fact that 103 or 18.1 per cent of the birds did not lay, as compared with 23 or 4.0 per cent in September. There were only 9 birds that did not lay in August, 7 in July, 3 in June, 1 in May and none in March and April.

The lower winter egg production is also partly accounted for by the number of birds that did not lay. Thus the number of birds that did not lay in the different winter months was 232 (40.8 per cent) in November, 109 (19.2 per cent) in December, 44 (7.7 per cent) in January and 31 (5.4 per cent) in February. In addition to the number of birds that did not lay a considerable proportion stopped laying for one or more weeks.

Table 4 and Figure 3 show that certain marked changes have occurred in the distribution of the production for the flock studied. The production in November has decreased significantly and there is also a slight decrease in December. On the other hand, production has increased decidedly in January and February with the result that the production during this four months period has increased. This period which is generally designated the winter period has received considerable attention in studies of inheritance of egg production. These studies have particularly emphasized the existence of a separate winter cycle in the egg production. As in the case of the

Table 4.—*Mean monthly egg production.*

	Hatched 1920	Hatched 1925	All Years 1920-25
November	11.12±.57	4.94±.53	7.28±.24
December	13.96±.54	11.52±.70	12.89±.26
January	11.15±.49	16.81±.59	14.74±.23
February	9.35±.40	18.27±.40	12.55±.22
March	21.91±.28	24.45±.25	21.72±.14
April	22.66±.25	23.04±.31	23.70±.10
May	20.35±.31	22.23±.40	22.37±.13
June	18.76±.33	20.07±.45	19.89±.14
July	17.77±.36	19.37±.48	19.02±.16
August	16.77±.39	17.53±.49	17.66±.16
September	14.15±.46	16.53±.46	16.14±.18
October	8.60±.58	12.56±.50	10.23±.21

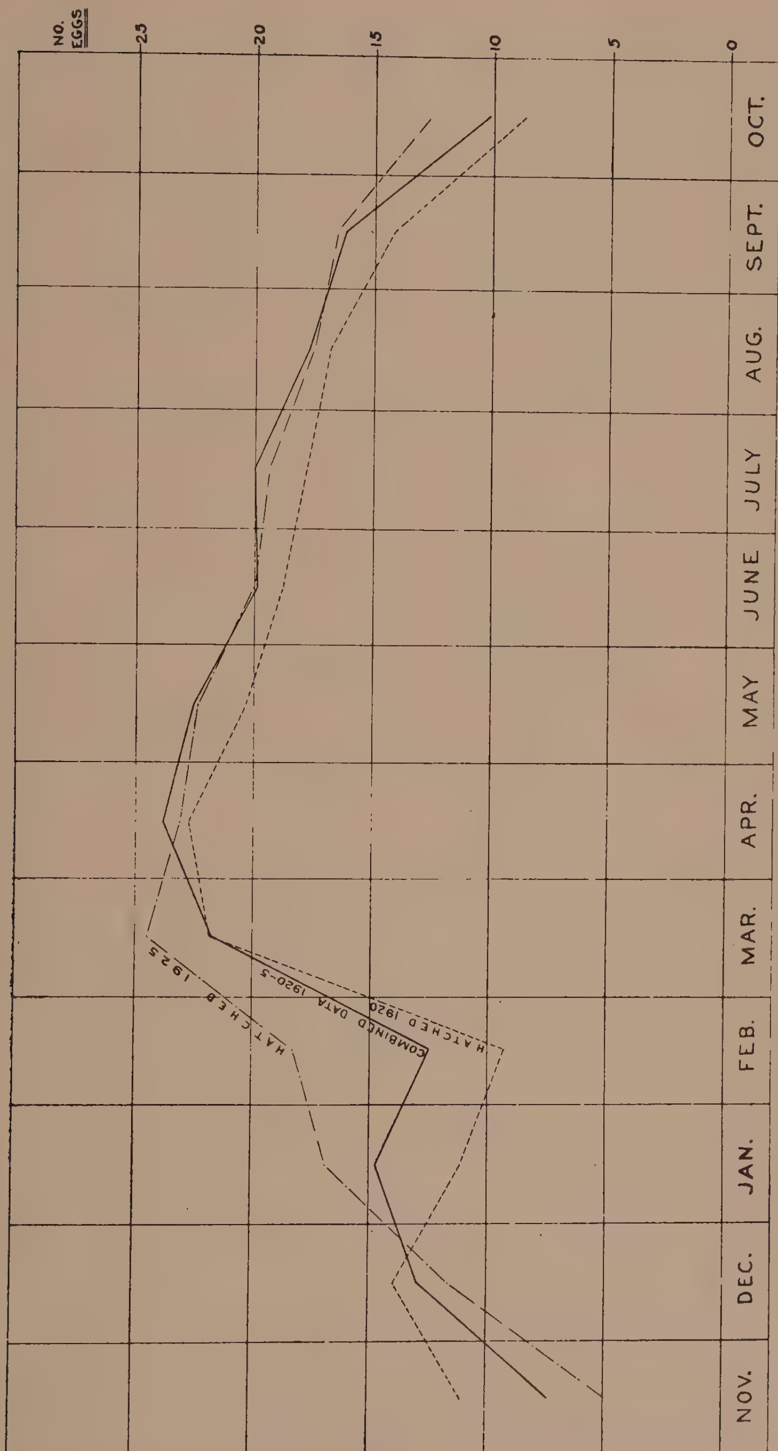

Figure 3. Average monthly egg production in the first laying year.

S. C. White Leghorns and S. C. Rhode Island Reds previously studied, s with the Barred Rocks, the changes that have occurred have obliterated a indications of a separate winter cycle. One of the explanations of this i the elimination of what Goodale (9) designated as a winter pause, possibl due partly to the tendency to start laying somewhat later, which is indicate by the lower production in November and December.

The effect of 'pauses' on egg production is indicated by the number o birds hatched in 1920 and in 1925 that 'paused' or stopped laying for a period of a week or longer but laid some eggs in January and February o their first laying year. Thus in 1921 when the production was 11.15 egg in January and 9.35 eggs in February (Table 4), 59.1 and 72.0 per cen respectively of the flock did not lay for a week or longer. In 1926 whe the production had increased to 16.81 eggs in January and 18.27 eggs in February the proportion of the flock that stopped laying had decreased t 31.6 and 20.0 per cent respectively.

Considering next the spring months it will be seen (Table 4 an Figure 3) that the peak of production which came in April in 1921 ha changed to March for the flock hatched in 1925. This change in the mont of highest production is due to a significantly large increase in the mea egg production for March and a negligible increase in April. The increas in the mean for March is apparently associated with the increase in Januar and February production and has previously been noted for White Leghorn and Rhode Island Reds whose production changed similarly to that o these Barred Rocks. Egg production also increased slightly in May, th third month of the spring period, but in spite of an increase in the numbe of eggs laid in this three months period, the proportion of the total (annual production laid in these months decreased slightly.

The increases in egg production noted for the spring months are als observed for the months of June, July and August, although the difference are slight. There is a somewhat greater increase in September and a stil greater increase in October 1926 over October 1921. Egg production i the two autumn months of September and October is of considerable prac tical and theoretical importance. It is therefore interesting to find (Table 4 that this is the only period in which there has been an increase in the pro portion of all eggs laid as well as in the actual number of eggs produced.

It will be noted from the foregoing discussion that egg productio decreased in November and December, the first two months, but increase more or less in every subsequent month. The increases are most marke in the months of January, February and March and in September an October at the beginning and end of the ten months period in which eg production increased. At least a part of the increased production ha been shown to be due to a decrease in the proportion of birds which d not lay for longer or shorter periods in these months. It would be interest ing to determine whether or not some of the increase is due to an increase i rate of laying during periods of actual production but this can only be don by a detailed analysis of individual records.

Some of the variations or changes in distribution of eggs laid in the first year are brought out more clearly in Figure 3. Thus a separate winter cycle is clearly indicated by the curve of egg production for the flock hatched in 1920 but is not apparent in the production of the birds hatched in 1925. The curve of production for the latter is more regular and the decrease in production after the peak has been reached in March is more gradual than in the case of the birds hatched in 1920.

It is interesting to note that the egg production of this flock of Barred Rocks was slightly lower in January and February 1921 than that reported by Pearl and Surface (*9*), although higher in every other month. The production of the pullets hatched in 1920 was also slightly lower than that of Barred Rocks in the Storrs Contest (*6*) in February, September and October. These months and one other, March, are the ones in which egg production increased most. The mean egg production for the entire flock (see last column, Table 4) is higher in every month than the production reported by Pearl and Surface and by Dunn. This higher egg production is apparently partly due to a lower percentage of zero producers in at least some months than the percentage found in the flocks studied by these investigators.

Variability in Monthly Egg Production

The standard deviation of the mean monthly egg production is shown in Table 5. This shows that the variability was greatest in December with November, January, February and October next in the order named. The variability, therefore, was much greater for the winter production of these Barred Rocks than for the production during any other period of the year. The variability as measured by the standard deviation was least during the three spring months of March, April and May. It increased gradually with decrease in production until October, but as pointed out the variabiltiy even in October was not as great as during the winter months.

The standard deviations for these Barred Rocks agree in a general way with those for the Rhode Island Reds in that they are highest for December and lowest for April. In the case of the Leghorns, the highest standard deviation came in November, but the production was least variable in April as in the case of the heavier breeds.

The changes that have occurred are shown by the standard deviations for the egg production of birds hatched in 1920 and 1925 (Table 5). There

Table 5.—*Standard deviation of the mean monthly egg production.*

	Hatched 1920	Hatched 1925	All Years 1920-25
November	8.10±.40	7.63±.37	8.35±.17
December	7.67±.38	10.14±.50	9.05±.18
January	6.94±.34	8.52±.42	8.15±.16
February	5.78±.29	5.83±.29	7.84±.16
March	4.00±.20	3.55±.17	4.84±.10
April	3.55±.18	4.51±.22	3.56±.07
May	4.40±.22	5.82±.28	4.76±.10
June	4.76±.24	6.18±.30	5.04±.10
July	5.10±.25	6.93±.34	5.57±.11
August	5.53±.27	7.08±.35	5.66±.11
September	6.54±.32	6.84±.33	6.36±.13
October	8.31±41	7.28±.36	7.55±.15

appears to have been an increase in the variability in December and a less marked increase in January. The variability also increased in April, May, June, July and August. There were also insignificant increases in February and September. The standard deviation decreased only in three months, those of November, March and October. None of these decreases is significant when compared with their probable errors. These changes would, therefore, seem to indicate that variability in egg production increased in most of the different months of the year.

Coefficient of Variation

The coefficients of variation are given in Table 6. Those based on the combined data for all years show that the relative variability was greatest in November with October, December, February and January next in order named. The differences in the coefficients of variation for December and October are very slight. Here again it will be seen that the greatest variability is in the winter egg production. The lowest coefficient of variation is again that for April with May and March next. There is a gradual increase in the coefficients of variation after April until September is reached. The coefficient of variation for October shows a marked increase over that for September due, of course, to the lower mean production (Table 4) and the greater absolute variability (Table 5).

Table 6.—*Monthly egg production—Coefficient of variation.*

	Hatched 1920	Hatched 1925	All Years 1920-25
November	72.83±5.16	154.59±18.18	114.61±4.36
December	54.93±4.56	88.08± 6.88	70.22±1.98
January	62.24±4.10	50.70± 3.06	55.29±1.40
February	61.82±4.06	31.93± 1.71	62.50±1.67
March	18.25±0.93	14.52± 0.73	22.26±0.47
April	15.67±0.79	19.59± 0.99	15.02±0.31
May	21.60±1.12	26.18± 1.37	21.29±0.44
June	25.37±1.33	30.76± 1.64	25.34±0.54
July	28.67±1.53	35.80± 1.96	29.28±0.63
August	32.97±1.80	40.39± 2.28	32.06±0.70
September	46.23±2.73	41.39± 2.35	39.38±0.90
October	96.63±8.09	57.99± 3.67	73.84±2.14

It is interesting in connection with the coefficients of variation to note that these Barred Rocks show greater variability during the winter months than did the Rhode Island Reds (*3*) which were kept under practically identical conditions. It may also be significant that the variability is less during the months of September and October. It seems probable that these differences in variability are due to inherent differences in these two flocks.

The coefficients of variation for egg production of birds hatched in 1920 and 1925 show that there has been an increase in relative variability in the months of November and December. The coefficients of variation decreased markedly in the month of February and also decreased in January and March, as was to be expected since egg production increased while the standard deviations remained practically the same. The coefficient of variation also decreased for October due to the increase in egg production and the decrease in absolute variability (standard deviation).

The coefficient of variation increased slightly during the months of April, May, June, July and August. None of these increases can be considered to be statistically significant, but the consistent increase in variability in all these months indicates a tendency towards greater rather than less variability for this period. This would seem to be strengthened by the increase noted previously in the standard deviation for these months. The evidence from Table 6 agrees with that from Table 5 that the tendency has been towards increased variability of this flock as indicated by the figures for the first and last year. As in the case of other breeds, the coefficient of variation has decreased for months or periods in which there was a marked increase in egg production and increased for months in which there was a significant decrease.

SUMMARY

Some of the more important information secured from this study of 569 records of first year egg production of Barred Plymouth Rocks may be summarized as follows:

1. Annual egg production increased by nearly 20 (19.89 ± 4.42) eggs or from 187 eggs in 1920-21 to 206 eggs in 1925-26. (Table 1).

2. The mean annual egg production of all birds that completed their records during six years was 198 eggs. This was found to agree very closely with records made by Barred Rock pullets entered in the official contests in British Columbia but higher than records made by Barred Rock pullets in other contests. (Table 2).

3. The proportion of pullets that laid 225 or more eggs doubled or increased from 16.1 per cent to 32.6 per cent. There was a corresponding decrease in the proportion of birds with records under 225 eggs. (Table 3 and Figures 1 and 2).

4. Egg production was lowest in November, increased slightly in December and January, again showed a slight decrease for February, with a marked increase in March and the highest production for the year occurred in April. Production after April decreased gradually until September and more rapidly in October. (Table 4 and Figure 3).

5. The lower production in certain months was found to be partly due to the number of birds that did not lay during these months as compared with the number of such zero producers in other months.

6. The increase in egg production was distributed over the ten months from January to October inclusive, with the greatest increases occurring in the first three and the last two months. There was a decrease in production in November and a slight decrease in December. (Table 4 and Figure 3).

7. The reduction in periods of non-production was shown to be partly responsible for the increased egg production in such months as January and February.

8. Variability in annual production did not apparently change from the first to the last year (Table 1) but variability in monthly egg production appears to have increased slightly as indicated by the standard deviation and coefficient of variation for the monthly production (Tables 5 and 6).

9. Variability in monthly egg production, as with other breeds, was least in the spring months (March, April, May) and greatest in the four winter months and in October. (Tables 5 and 6).

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BREEDING FOR DISEASE RESISTANCE WITH PARTICULAR REFERENCE TO THE SMUT OF OATS*

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Introduction

Wherever crop plants are cultivated plant diseases may be found and often these diseases determine the difference between success and failure in production. It is natural then that the plant breeder has given in the past, and undoubtedly will continue to give in the future, considerable attention to controlling these diseases by breeding.

We know from numerous tests that not only do different varieties and strains of host plants differ strikingly with regard to their reaction to a certain pathogene, but that many disease producing organisms are themselves composed of strains or physiologic races which may be similar morphologically but differ widely in their parasitic capabilities. The discoveries of the pathologist and of the geneticist during the past 15 years have given us a much better appreciation of the nature of certain plant diseases and new ideas as to their control.

It has not been many years since our friends the plant pathologists were rather skeptical about accepting the plant breeders' contention that a difference in resistance to a plant disease might be due to inherent genetic conditions in the host plants. It was rather generally held among pathologists that susceptibility and resistance were largely determined by environment and therefore not inherited. In fact many plant breeders, even after they had thoroughly demonstrated that heritable differences in reaction to disease did occur, thought that the manner of inheritance of such a character as disease resistance was quite different from the manner of inheritance of ordinary qualitative characters.

In some respects the earlier ideas regarding the manner of inheritance of disease resistance were similar to those regarding the inheritance of quantitative characters. But, just as a clearer insight into the nature of size inheritance has been attained, through linkage studies, particularly the work of Sax and of Lindstrom, so likewise our present ideas regarding the manner of inheritance of disease resistance has been very much clarified by linkage studies. An important contribution in this field is the work of Griffee *(6)*† with *Helminthosporium sativum* in barley at the Minnesota Station. He found that there were at least three factors concerned in producing resistance of the type possessed by the variety Svanhals. One of these factors was found to be linked with the factor for two-rowed; one with the factor for white glumes, and one with the factor for rough awns. In addition to the linkage studies there have been reported numerous instances of resistance to disease inherited in a simple Mendelian manner. The extensive evidence

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†Numbers refer to literature cited.

TABLE 1.—*Per cent smut infection in certain strains of selfed maize.*

Name of strain in 1927	1922 No. of plants	1922 Per cent infection	1923 No. of plants	1923 Per cent infection	1924 No. of plants	1924 Per cent infection	1925 No. of plants	1925 Per cent infection	1926 No. of plants	1926 Per cent infection	1927 No. of plants	1927 Per cent infection	Average per cent infection
4–14–2–1–1–1–1–1	52	0.0	24	4.2	20	0.0	86	2.3	82	0.0	43	2.3	1.5
4–17–1–1–1–1–1–1	49	4.1	21	0.0	19	0.0	80	2.5	96	1.0	97	1.0	1.4
4–30–3–2–1–1–1–1	50	4.0	21	0.0	21	0.0	35	0.0	41	2.4	34	0.0	1.1
5–2–2–1–1–1–1–1	52	0.0	23	4.3	24	0.0	91	0.0	94	1.1	96	1.0	1.1
8–24–1–1–1–1–1–1	52	1.9	25	4.0	24	0.0	89	3.4	93	3.2	76	0.0	2.1
1–5–1–2–1–1–1–1	53	9.4	25	8.0	25	20.0	92	27.2	98	33.7	31	29.0	21.2
2–1–1–1–1–1–1–1	37	13.5	25	16.0	19	26.3	31	71.0	65	35.4	91	31.9	32.3
3–8–1–1–1–1–1–1	51	56.9	16	56.3	72	26.4	25	12.0	77	6.5	16	12.5	28.4
8–15–1–1–2–1–1–1	52	1.9	24	25.0	26	23.1	94	24.5	89	30.3	87	14.9	19.9
6–10–1–1–1–5–5–1	43	46.5	150	23.3	96	77.1	1031	53.6	1015	53.1	819	70.3	54.0

TABLE 3.—*Percentage of smutted plants among the parents and F_3 families of an oat cross, Gopher X Black Mesdag and the reciprocal grown in 1926.*

Name	Class centers in percentage: 0	2.5	7.5	12.5	17.5	22.5	27.5	32.5	37.5	42.5	47.5	52.5	57.5	62.5	67.5	No.* of parental plots & F_3 families
Gopher	1	1	1	1	0	3	2	1	1							11
Black Mesdag	11															11
F_3 Families	21	18	25	16	0	3	4	3	3	2	0	1	3	0	1	100

*Most of the parental and F_3 plots contained from 60 to 65 plants.

which has been collected shows conclusively that resistance to disease may be inherited just as definitely as color of grain. Relative resistance to disease may be more dependent on environment for its final expression than is a qualitative character like color of grain, but in each case there is a definite genetic background for the development of the character.

Resistance to Smut in Maize

There is perhaps no better material for illustrating heritable differences in disease resistance than selfed lines of maize. In 1920 a number of self-pollinations of maize were made at the West Virginia Agricultural Experiment Station and from these pollinations and others which have been made subsequently a number of selfed lines have been established. These lines have been grown continuously on the same field and under conditions to encourage smut (*Ustilago zeae*) epidemics.

The selfed lines differ strikingly not only with respect to morphological attributes but also with respect to resistance to smut. In the first column of Table 1 is given the 1927 strain number of the selfed lines. The number of integers separated by dashes in each strain name is the number of years less one that that particular strain had been selfed in 1927. It will be noted that all the lines reported in Table 1 had been selfed seven years in 1927 and thereby had undoubtedly attained a high degree of homozygosity.

The first five lines listed in the table show consistently a high degree of resistance to smut. The average infection from 1922 to 1927 inclusive ranges from 1.1 to 2.1 per cent and in no year is the infection in any one of the five lines greater than 4.3 per cent. The next four strains listed in Table 1 show a medium high average percentage of smut infection. The first two lines of this group show relatively low infection in 1922 and 1923 and a high infection from 1924 to 1927 inclusive, whereas the third line (3-8-1-1-1-1-1-1) of the group shows just the opposite tendency. Line 8-15-1-1-2-1-1-1 showed a low percentage infection in 1922 but has shown a medium high infection since that time. It is reasonable to suppose that these differences in smut infection obtained in the early and in the later years of the selfed lines is, in part at least, of a genetic nature.

Several investigators have shown not only that it is possible to isolate selfed strains of maize which differ strikingly with regard to smut infection, but that it is likewise possible to isolate susceptible strains which differ a great deal with respect to place of infection. Some strains may be rather generally infected, others may be infected primarily near the base, others on the ear and still others in the tassel.

In Table 2 are listed a few strains which have shown a high degree of localization of smut infection. Line 8-1 etc might be called a base strain as it has shown more smut boils at the base of the stalk than on any other region of the plant. In 1925, seven plants showed smut boils of which six were at the base of the plants, and in 1926 of the 41 infected plants 26 were base, 8 more below ear, 2 ear, 4 leaf, and 1 tassel. One of the 26 plants which showed a smut boil at the base also showed smut infection elsewhere on the plant. This is indicated in the table by a + sign. Similarly in other places in the table where there are two numbers recorded in a single blank, the one

TABLE 2.—*Location of smut infection in certain selfed strains of maize.*

Name	Year Crown	No. of plants	No. of plants infected in Tassel	Neck	Leaf	Ear	Below Ear	Base
8–1–1–1–1–1	1925	30	1					6
8–1–1–1–1–1–1	1926	94	1		4	2	8	26 1+
8–15–1–1–2–1	1925	94	22					1
8–15–1–1–2–1–1	1926	89	25		1	1		
8–15–1–1–2–1–1–1	1927	87	10				3	
6–30–2–1	1925	87	14					3
6–30–2–1–1	1926	94	38				2	
6–30–2–1–1–1	1927	86	27					
9–7–1–1	1925	88	36 2+		1			
9–7–1–1–1	1926	84	30		1		1	2
6–27–1–1–1	1925	56	2		3	10		
6–27–1–1–1–1	1926	90	29 5+			9		
5–10–1–1–1–1	1925	94	3 2+	1	5 1+	21 2+		
5–10–1–1–1–1–1	1926	100	9			25 1+		
1–16–1–1–1–1	1925	39	2	8		10 5+	3	1
1–16–1–1–1–1–1	1926	57	3	1		12 4+	9 2+	13 5+
1–16–1–1–1–1–1–1	1927	96				4		
10–13	1926	95		9 2+	1		2	
10–13–1	1927	83		22 6+	1	1	4	
10–13–2	1927	83		30 2+	1		4	
5–3–1–1–1–1	1925	69			4			
5–3–1–1–1–1–1	1926	82			5			
5–3–1–1–1–1–1–1	1927	6			3			

A word of explanation is necessary with regard to place of infection. A smut boil below the second internode at the base of the plant was considered as basal infection. Between this region and the node at which the ear appeared was considered "below ear." The "neck" was considered immediately below the tassel. Leaf sheath was included with leaf.

with a plus sign indicates the number of plants infected elsewhere with smut in addition to the place indicated in the column heading.

Strains 8-15 etc., 6-30 etc., and 9-7 etc., were predominantly infected in the tassel whereas strain 6-27 etc., had a rather low tassel but high ear infection in 1925 and a high infection in both ear and tassel in 1926. Strains 5-10 etc., and 1-16 etc., were predominantly infected in the ears, although the latter showed a rather high basal infection in 1926. Strain 10-13 etc., has shown consistently a relatively great number of plants infected with smut in the region of the stalk, immediately below the tassel (neck) and strain 5-3 etc. showed leaf infection only in 1925 to 1927 inclusive. The data in Table 2 indicate clearly that a striking difference in locus of smut infection may be obtained among selfed strains of maize.

The Smut of Oats

Loose smut (*Ustilago avenae*) and covered smut (*Ustilago levis*) are among the most common and destructive of fungi which attack oats. In West Virginia the rough-spored species which causes the so-called "loose smut" is by far the more common. It is true that these diseases are quite readily controlled by the use of formalin or some newer preparations recently placed on the market yet it is generally agreed that the most satisfactory control measure is to develop varieties of oats resistant to the disease. It was with this object in view that the investigation reported here was begun.

Material and Methods

Gopher, a selection made from Sixty-Day oats at the Minnesota Station was crossed with Black Mesdag. Gopher is high yielding and moderately

susceptible to both loose and covered smut, whereas Black Mesdag is a rather low yielder, at least under West Virginia conditions, but possesses marked resistance to both forms of smut. During one year the reaction of the parental material to loose smut and to covered smut was studied separately but no difference was detected. Gopher proved moderately susceptible and Black Mesdag proved resistant to both forms of smut. After this test was made no particular precaution was used in collecting the smuts to keep them separate, but by far the greater part of that collected and used in infecting the seed was loose smut.

In a rather extensive survey of the reaction of oat varieties, which included Black Mesdag and Sixty Day, to covered and loose smut, Reed (*7*) concluded that there were no apparent differences in the infection capacity of the two species of smuts. In a later paper Reed (*12*) found some varieties of oats that seemed to be more susceptible to loose smut than to covered smut and *vice versa*. Sampson (*14*) and Reed (*8, 10*) have published data that indicate the existence of biological strains of loose and covered smuts of oats, all of which complicate somewhat the problem of breeding for resistance.

In the investigation reported here considerable difficulty was experienced in obtaining a satisfactory epidemic. In some preliminary experiments seeds were treated with various materials before treating with smut, some were dehulled before treating, and various other methods were tried. The method which was finally adopted was to place a "pinch" of smut in an envelope containing the seed for a certain plot and then shake the envelope vigorously. The seed was usually treated some three or four weeks before planting time.

The seed was planted during the first two weeks of June as it was found that by deferring seeding until this relatively late date a more satisfactory smut epidemic was obtained. Soil temperature records were kept by means of a soil thermograph and some study was given the soil moisture. The responsibility for creating the smut epidemics and the study of the relation between various environmental factors and smut infections, was undertaken largely by the Department* of Plant Pathology. A more detailed report of this phase of the work may be published later. It suffices here to state that moisture and temperature are of considerable importance in connection with smut infection as has been shown by other workers (*2, 11*).

In an investigation reported recently by Gage (*4*) it was found that in general slow germination of oats and continued slow development of the plants favored smut infection. Smutted panicles were not found to be a very trustworthy criterion of infection as it was shown that a plant might be infected and yet not produce smutted panicles. It was also shown that the greatest number of smutted panicles was obtained by inoculating oats during blossoming time. A considerably smaller number of smutted panicles was obtained when the oat seeds were dehulled and treated with smut spores immediately after harvest, although even in this case a quite satisfactory infection apparently was attained. A considerably smaller number of smutted plants was found among those lots in which the seed was dusted at harvest

*Breeding oats for smut resistance as it is carried on at the W. Va. Experiment Station is a joint project between the Departments of Plant Pathology and of Agronomy and Genetics.

time but not dehulled. Hulless oats treated in a similar manner gave evidence of a fairly heavy infection.

Gage states, "Granting that some seedling invasion may result from spores which remain dormant, and also from mycelium in the glumes, it is still very evident that the majority of such invasions in both oat smuts are the result of mycelium developed in or on the pericarp from spores which lodge inside of the blossoms at pollination time."

All plant material in the experiment conducted at Morgantown was grown in short rows and spaced so that individual plants could be readily distinguished. The smut notes were taken twice each season, the first time just after all the strains were "fully headed" and the second sometime later but before the oats had fully matured. The percentage of plants with smutted panicles was determined for each family.

In 1926 an F_3 and in 1927 an F_4 population was produced under fairly satisfactory smut epidemic conditions. Check plots of each parent distributed at regular intervals were grown among the F_3 and F_4 families. In 1926 each F_3 family was grown in a single plot consisting of three rows 6 feet long but in 1927 each F_4 family was grown in duplicate plots each plot consisting of two rows 5 feet long. In the former year 25 seeds per row and in the latter year 20 seeds per row were planted, thus making a total of 75 seeds of each F_3 family and of 80 seeds of each F_4 family. The same number of seeds was planted in each parental plot as was used in each progeny plot in the two years respectively.

The method of inducing smut infection used in this experiment did not give a sufficiently great number of smutted panicles among the susceptible plants to warrant a genetic analysis based on an F_2 generation. For this reason no attempt was made to determine the manner of inheritance of resistance to smut until a third generation was available.

On June 9, 1926, 100 F_3 families of the oat cross, Gopher x Black Mesdag and the reciprocal, were seeded in the oats nursery at Morgantown. Each F_3 family was seeded in a plot of three rows with twenty-five seeds per row. Two adjacent parent plots occurred every 10 plots in the nursery and thus gave a fairly satisfactory check as to the extent of the smut epidemic.

The Gopher parent has been classified as moderately susceptible to smut. The heaviest smut epidemic that has been obtained in connection with this project occurred in 1926. From Table 3 it may be seen that one of the Gopher plots showed no smutted panicles and the 10 others ranged between .1 and 39.9 per cent smutted plants. Three of the plots showed percentages of smutted plants between .1 and 14.9, five of the plots between 20 and 29.9 and two between 30 and 39.9. It is evident that the Gopher parent manifested considerable variability with regard to degree of smut infection as indicated by smutted panicles. The Black Mesdag parent did not show a single smutted panicle in 11 plots.

Of the 100 F_3 families, 21 showed no smutted plants thus indicating that a single main factor difference was responsible for resistance. On the basis of this assumption the theoretical number of homozygous resistant families is 25, a deviation of 4 ± 2.9 from the number actually obtained.

The range in the percentage of smutted plants among the other 79 F_3 families was from a class center of 2.5 to one of 67.5. The great majority of the families in which smutted plants were found fell into three classes, namely, those with class centres of 2.5, 7.5, and 12.5. In all there were 59 F_3 families in these three classes. Fifteen families showed percentages of smutted plants between 20 and 45 and five families between 50 and 70. This latter group of five families is of particular interest from a genetic standpoint as they indicate that transgressive segregation with regard to smut susceptibility possibly has occurred. In addition to the four families two others showed a greater percentage of smutted plants than did any of the plots of the susceptible parent. However, those two families showed a percentage of smutted plants only slightly higher than the Gopher plot with the highest percentage and therefore might not arouse suspicion. The situation is quite different with respect to the five F_3 families which showed a markedly higher percentage of smutted plants. The possibility that they possess a genotype more susceptible to smut than that of the Gopher parent is clearly indicated. In order to obtain more data on this question, as well as others, 158 F_4 families were grown in 1927.

F_4 Families

The percentages of smutted plants among the F_4 families and the parents are shown in Table 4. It will be recalled that each F_4 family was grown in duplicate plots and the parents were grown in systematically distributed plots throughout the nursery. There were in all 33 plots of each parent but since the percentage of smutted plants among the F_4 families were based on duplicate plots the percentages of smutted plants among the parents were likewise based on duplicate plots and these were distributed in the same way as the F_4 families, i.e., there were the same number of plots intervening between duplicate plots of the parents as there were between duplicate plots of the F_4 families. This arrangement made available 16 pairs of duplicate plots of each parent on which to make the determinations of the percentage of smutted plants.

The 158 F_4 families grown in 1927 came from plant selections of 30 different F_3 families grown during the preceding year. Five F_4 families were produced from each of the 30 F_3 lines except 16-15-17 and 17-10-48 of which 8 and 10 respectively F_4 families were grown. In general F_4 families from resistant F_3 lines were planted adjacent to F_4 families from susceptible F_3 lines.

Fifteen out of sixteen duplicate plots of the Gopher parent showed percentages of smutted plants which fell in the range from 2.5 to 12.5 inclusive, thus indicating moderate susceptibility. The other duplicate plots showed 21.4 per cent of smutted plants which was the maximum percentage obtained in the Gopher parent in 1927. The Black Mesdag parent, as in 1926, did not show a single smutted plant. The F_4 families which came from the zero F_3 lines did not show any smutted plants except in two instances. Of the five F_4 families from 16-15-59 four showed smutted panicles clearly indicating that the parental F_3 family was not homozygous for smut resistance but simply escaped infection or at least did not show any external

evidence of infection. In one other instance an F_4 family from a zero F_3 line showed some smut but in this case only one of the five F_4 families showed any smut and this one showed it in a single plant only. A further test of this family is being made. It is possible that the smutted plant may have been an accidental mixture.

The five highly susceptible F_3 families, 16-15-39, 17-10-21, 17-10-64, 17-10-68, and 17-10-75 all produced only susceptible F_4 progenies and one of these, 17-10-68, is clearly more susceptible than the susceptible parent. Each of the five F_4 families from this F_3 line produced a higher percentage of smutted plants than was produced by any plot of Gopher. The percentage of smutted plants among the F_4 families was from 27.5 to 42.5 whereas among the duplicate plots of Gopher the range was from 2.5 to 22.5 and all but one of these duplicates were below 15.0. This is of particular interest from a genetic standpoint as it indicates that transgressive segregation has occurred.

Table 4.—*Percentage of smutted plants among the parents, the F_3 families and the respective F_4 families grown from them of an oat cross, Gopher X Black Mesdag and the reciprocal.*

Name	No. of plants	Per cent smutted plants	No.* of F_4 families and duplicate parental plots	Percentage of smutted plants (class centers) 0	2.5	7.5	12.5	17.5	22.5	27.5	32.5	37.5	42.5
Gopher P			16		3	7	5		1				
Black Mesdag P			16	16									
16–15–4	64	0	5	5									
16–15–8	66	1.5	5	3	1		1						
16–15–7	64	12.5	5	1	3	1							
16–15–39	60	55.0	5				2	2		1			
16–15–16	70	0	5	5									
16–15–31	66	1.5	5	2	3								
16–15–1	51	13.7	5	2	1	2							
16–15–21	70	27.1	5			3			1	1			
16–15–17	70	0	8	8									
16–15–35	63	0	5	5									
16–15–36	54	20.4	5	2	1	1	1						
16–15–53	69	0	5	5									
16–15–55	70	27.1	5		1	1	1	1		1			
16–15–59	65	0	5	1	3	1							
16–15–64	60	0	5	5									
16–15–68	73	28.8	5		2		3						
17–10–1	68	0	5	5									
17–10–21	65	56.9	5				2	1	1	1			
17–10–22	65	1.5	5	1	2	1	1						
17–10–35	65	27.7	5	1		1	2	1					
17–10–30	61	0	5	4	1								
17–10–54	63	11.1	5	3	1		1						
17–10–62	67	0	5	5									
17–10–64	67	50.7	5				2	1	1	1			
17–10–52	70	0	5	5									
17–10–68	55	65.5	5							1	2	1	1
17–10–53	68	0	5	5									
17–10–75	71	57.7	5				1	2		2			
17–10–72	65	1.5	5	2	1	2							
17–10–48	65	0	10	10									

*Most of the duplicated parental and F_4 plots contained from 65 to 70 plants. Thirty-two plots of each parent were grown, thus making 16 duplicates comparable to the F_4 families.

Each of the other four highly susceptible F_3 lines produced one or more F_4 families that were more susceptible than the most susceptible plot of the Gopher parent. The F_4 breeding behavior indicated that the highly susceptible F_3 lines were homozygous for at least one main factor for susceptibility to smut.

TABLE 5.—*The breeding behavior of certain F_3 families as revealed in the F_4 generation of an oat cross, Gopher X Black Mesdag and the reciprocal.*

Percentage of smutted plants in F_3	0		.1 – 9.9		10 – 19.9		20 – 29.9		30 –	
Breeding nature as shown in F_4	Homo.	Seg.	Homo.	Seg.	Homo.	Seg.	Homo.	Seg.	Homo.	Seg.
Number of F_3 families	12	1		4		3	3	2	5	

A summary of the breeding behavior of each F_3 line tested in F_4 is shown in Table 5. It is obvious that all the F_3 lines with a low percentage of smutted plants showed segregation in F_4. Of the five F_3 families which showed a percentage of smut infection between 20 and 29.9 in 1926, three were apparently homozygous for at least one main factor difference for susceptibility and two segregated. The five highly susceptible F_3 lines and eleven of the twelve F_3 lines in which no smutted plants were found, bred true for these respective characteristics in F_4 with the exception of a single plant which was smutted among the resistant strains.

INHERITANCE* OF RESISTANCE TO SMUT

The data based on the F_3 and F_4 generation of the oat cross Gopher x Black Mesdag and the reciprocal, indicate that resistance to smut is an inherited character with a single main factor difference, operating to determine resistance. In addition to this factor however, there is at least one other that conditions the expression of the character. It is clearly evident that transgressive segregation with respect to susceptibility occurred in the cross. F_3 as well as F_4 families were obtained in which a distinctly greater percentage of smutted plants was found than in any of the plots of the susceptible parent.

Gopher seems to be moderately susceptible to smut and Black Mesdag seems to be either highly resistant or completely immune. The latter parent however, brought something into the cross which when combined with the susceptibility of Gopher gave segregates which were markedly more susceptible than the Gopher parent. A considerable number of F_3, F_4, and F_5 families are being grown this year to determine more fully the manner of inheritance of resistance to smut.

*Since this was written a paper by Hayes, Griffee, Stevenson, and Lunden has appeared in which they report the inheritance of smut reaction in certain oat crosses between strains of hybrid origin and Black Mesdag. On the basis of the progeny tested in F_3 to F_5 for smut reaction 86 lines were as susceptible as the susceptible parent, 47 lines immune like the Black Mesdag parent, 36 lines were classed as highly resistant and the 209 remaining lines produced some smut infection although less than the susceptible parent and more than the lines classed as resistant. The following suggestion is made. "The genetic factors for smut reaction cannot be determined with accuracy in these studies. Results of the same general nature received here could be obtained by two factors I and R for immunity and resistance, respectively, both carried in the Black Mesdag parent, each allelomorphic to factors for susceptibility with the further hypothesis of I epistatic to R. This, however, is suggested only as a possible explanation."

No linkage was found between smut reaction and color of seed.

Hayes, H. K., Griffee, Fred, Stevenson, F. J., and A. P. Lunden. 1928. Correlated studies in oats of the inheritance of reaction to stem rust and smuts and of other differential characters. Jour. Agr. Res., Vol. 36(5):437-457.

In a cross between Red Rustproof (*A. byzantina*) and Black Tartarian oats (*A. sativa orientalis*) Wakabayashi (*15*) found resistance to covered smut to be dependent upon multiple factors and completely dominant in its inheritance. In a later investigation Barney (*1*) at the Cornell Experiment Station concludes "that some varieties of oats contain one factor pair for resistance to loose smut, that other varieties contain two independent factor pairs, while in other varieties three factor pairs may be concerned with resistance". The factorial analysis was based largely on the results obtained in the F_2 generation.

In 1925 Reed (*9*) presented data from a cross between *Avena nuda* variety inermis and *A. sativa* variety Black Mesdag which indicated that resistance to loose smut was inherited as a dominant character and dependent for its expression on a single factor difference between the two parents. Reed and Stanton (*13*) studied the inheritance of resistance to both loose and covered smut in a cross between Fulghum and Swedish Select and also explained their results on the basis of a single factor difference. The F_3 and F_4 selections reacted in the same manner toward both loose and covered smut. No correlation between reaction to smut and any morphological character was found.

Gaines (*5*) presented data on the inheritance of resistance to covered smut in four crosses between Red Rustproof as the resistant parent and Black Tartarian, Abundance, Large Hulless and Chinese Hulless as the susceptible parents. It is stated that "the crosses with Black Tartarian and Abundance indicate that Red Rustproof carries three dominant factors for immunity, any one of which prevents the production of covered smut spores. In crosses with Large and Chinese Hulless, one factor apparently does not give complete dominance in Hulless segregates, but otherwise the prepotency of the factors for immunity is similar in all four crosses."

Correlated Inheritance

In the oat cross reported here the inheritance of certain other characters in addition to resistance to smut has been studied and will be published in the near future as a West Virginia Agricultural Experiment Station Technical Bulletin. A brief summary of the results of this study is given here. The genetic analysis was based on 455 F_2 plants, and 139 F_3 families grown in one year, and 622 F_2 plants and 150 F_3 families grown in another year. One of the characters studied was earliness. It was found to be inherited as a dominant and some evidence was obtained which indicated that there were at least two factor differences concerned. Leaf width determined at the widest part of the second leaf numbering from the top down, proved to be a variable character and one that was influenced to a marked degree by environment. Data were obtained which showed that leaf width was an inherited character but the manner of its inheritance was not determined. The distribution obtained in the F_2 generation and the behavior of the F_3 families with respect to leaf width was rather typical of what occurs when a cross is made involving a quantitative character dependent on multiple factors for its expression. One F_3 family grown in 1924 had a mean leaf width significantly less than the mean leaf width of any plot of Gopher

the narrow-leafed parent. Black seed of the Black Mesdag parent was found to be dominant to white seed of the Gopher parent and to be dependent for its expression upon a single factor difference.

Relation Between Earliness and Smut Resistance

The Gopher parent heads about ten days earlier, on the average, than the Black Mesdag parent. The 100 F_3 families grown in 1926 were examined to see if there was a tendency for the relatively early heading strains to be more susceptible to smut than the later heading strains. It is obvious from the data in Table 6 that no marked positive correlation between "Date Headed" and "Percentage of smuted plants" exists. The correlation surface presents a rather typical scatter diagram with most of the variables falling in the lower classes of percentage of smutted plants. No evidence of genetic linkage between smut susceptibility and earliness is apparent from these data.

Table 6.—*Correlation surface showing "Date Headed" subjective, and "Percentage of smutted plants" relative, in the F_3 families of an oat cross, Gopher X Black Mesdag and the reciprocal grown in 1926.*

Date headed	PERCENTAGE OF SMUTTED PLANTS															
	0	2.5	7.5	12.5	17.5	22.5	27.5	32.5	37.5	42.5	47.5	52.5	57.5	62.5	67.5	Total
4	3		1													4
5	1	2	5							1						9
6	5	4	4	5		2	1		1							22
7	4	4	8	2		1							1			20
8	4	2	4	7			2	1	1				1		1	23
9	2	1	3	2								1				9
10	1	4					1	1					1			8
11	1							1	1	1						4
12		1														1
	21	18	25	16		3	4	3	3	2		1	3		1	100

Relation Between Color of Grain and Smut Resistance

Of the hundred F_3 families (Table 7) grown in 1926, 26 bred true for black grain, 23 bred true for white grain, and 51 segregated and of the 21 families in which no smutted plants were found 8 were black-seeded, 8 segregated for color of seed, and 5 were white-seeded. Distributions with respect to percentage of smutted plants in each of the three categories with black, segregating, and white are similar thus indicating that color of seed and the main factor for smut resistance are not linked in inheritance.

On the other hand the data although meagre, indicate the possibility of a linkage relation between the factor for black seed color and a supplementary factor which brings about transgressive segregation for smut susceptibility.

Table 7.—*A correlation surface showing "color of grain" subjective and "percentage of smutted plants" relative, in the F_3 families of an oat cross, Gopher x Black Mesdag and the reciprocal grown in 1926.*

	PERCENTAGE OF SMUTTED PLANTS															
	0	2.5	7.5	12.5	17.5	22.5	27.5	32.5	37.5	42.5	47.5	52.5	57.5	62.5	67.5	Total
Black	8	5	5	3		1	1			1		1			1	26
Segregating	8	7	19	9			2	2	1				3			51
White	5	6	1	4		2	1	1	2	1						23
	21	18	25	16		3	4	3	3	2		1	3		1	100

It will be observed from Table 7 that all five of the F_3 families which showed a high percentage of smutted plants were either black-seeded or segregated for seed color. Further data are needed to clear up this point.

Relation Between Width of Leaf and Smut Resistance

In an earlier study it was shown that width of leaf was an inherited character. In order to determine whether a linkage existed between this character and reaction to smut a preliminary experiment was carried on in 1927. Since Black Mesdag has wide leaves and Gopher narrow leaves one would expect the narrow-leafed segregates of a cross between them to be more susceptible to smut on the average than the wide-leafed segregates providing a genetic linkage existed. A composite sample of seed was made up by taking 10 seeds from each of 45 narrow-leafed F_2 plants and another similar composite sample by taking 10 seeds from each of 44 wide-leafed F_2 plants. Those two lots of seed were treated with smut and planted in short alternate rows. Out of a total of 386 F_3 plants from the narrow-leafed F_2 plants, 9 were smutted and out of 372 F_3 plants from the wide-leafed F_2 plants 20 were smutted.

In addition to the evidence just presented, data were collected from some of the F_3 families. Measurements were made of mean leaf widths of families free of smut and of families in which smutted plants were found. Both wide- and narrow-leafed F_3 families were found among the smutted group as well as among the group free from smut, thus indicating that if there was any genetic linkage at all between leaf width and resistance to smut it was a very loose one.

Discussion and Conclusions

Breeding plants for resistance to disease is both fascinating and profitable. The discoveries which have been made during the past twenty years have shown conclusively that resistance to disease is definitely inherited in a manner entirely analogous to that which obtains for other plant characters. The situation has been complicated somewhat by the discovery that pathogenes as well as hosts may differ genetically but nevertheless it is recognized that one of the most satisfactory and permanent measures for controlling a particular plant disease is by means of breeding. Unfortunately it is not possible to control all plant diseases in this way and of course in these cases it is necessary to use some other method of attack. When complete immunity or high resistance to a certain disease exists in a host plant, this character may be transferred easily by hybridization to other varieties or even to closely related species.

In inheritance studies it is desirable that the host plants used as parents be pure line material and that the pathogene be of a single biological form. Some of the more recent work in the field of plant pathology indicates that the breeding of plants for resistance is likely to be further complicated by the lack of stability in the pathogenes. The work of Christensen and Stakman (*3*) with the smut of corn indicates that mutations may arise in the fungus and some of these mutants may be more virulent than the parent form. These complications serve only to make the joint problem of the pathologist and the geneticist more interesting, although the attainment of the desired aim may be postponed.

If it is possible to obtain from a cross segregates which are more susceptible than the susceptible parent as was done in the experiment reported here, it seems reasonable to expect that transgressive segregation with respect to resistance may also occur. This possibility may prove of value in those cases where neither of the parents possesses complete immunity.

The inheritance of reaction to smut in the cross Gopher x Black Mesdag seems to be controlled by a single main factor difference. In addition to this main factor there is at least one supplementary factor, presumably brought in by the Black Mesdag parent, which causes transgressive segregation for susceptibility. Segregates were obtained in the F_3 and F_4 generations which were more susceptible to smut than the susceptible Gopher parent. Some evidence was obtained which indicates that this supplementary factor is linked with the factor for black color.

In conclusion then it may be stated that although the problem of breeding plants for resistance to disease is not as simple as it formerly seemed, it nevertheless offers one of the most satisfactory means of controlling numerous plant diseases. Considerable has already been accomplished by breeding in controlling such diseases as the smuts and rusts of the cereals, anthracnose in red clover and beans, wilt in cotton, flax, and cowpeas, root rots of tobacco and cabbage, but there is still much to accomplish. One of the most promising opportunities for the plant breeder to increase production is by breeding for resistance to disease.

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THE DEVELOPMENT OF AGRICULTURAL ECONOMICS*

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Three interpretations of the word development in this subject appear interesting. The development of the Canadian farm as it now exists is in itself a fascinating story. The past development of economics as applied to farming is also a phase which might be made interesting as it is obvious that considerable has already been accomplished in this line. These somewhat alluring phases of the subject must on this occasion be superceded by one that is perhaps more difficult and controversial but certainly more pressing, namely the possible future development of agricultural economics which is the proposed topic of discussion.

The question is what assistance—if any—may this science afford the farming industry? The firm conviction that the development of this subject offers possibilities of a valuable contribution to the progress of the industry, the welfare of which is here our common cause, renders it a privilege indeed to submit a few remarks for your consideration.

The economics of agriculture is by no means a new subject. But in Canada it is somewhat youthful. This is not surprising. Until a few decades ago farming in this country as elsewhere was considered as a more or less self-sufficing mode of existence. In the commercialized farming which now confronts us the farmer like everyone else must seek first the kingdom of money in order to insure that a reasonable proportion of the comforts and amenities of life may later be added unto him. Under such conditions business problems increase continually in importance. The farming industry can neglect this only at its peril.

Economists have for some time been devoting their attention to labour problems, schools of commerce are no recent development and at present banks, transportation companies and all large enterprises appear fairly well equipped with economists and statisticians. The importance of farming in the national economy of this country would appear to warrant a similar development for the farming business. The development of this subject offers possibilities of a definite contribution in many lines. Among them we may include:—

1. Marketing and Cooperation

Fortunately for the brevity which is necessary, accomplishments along this line by this association make treatment in detail superfluous. Accomplishments here however only indicate possibilities. Cooperation may secure for a business carried on by small units some of the advantages of large scale industry. Here as frequently elsewhere results have not always been exactly the achievement of aims. Cooperative marketing offers opportunities *not* from the elimination of the middleman but *rather* through the supplying of a better service. Its advantages come *not* through the arbitrary control of production and price but *rather* from more accurately equating supply and demand.

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This reveals how marketing is very largely a production problem. In fact the elimination of the middleman is an idea resulting from inadequate analysis of what production includes. A commodity is produced only when it is in the form required at the place required at the time required. We have groups of people giving goods the desired form, others transporting them from where they are not wanted to places where demand exists and others storing the superabundance against periods of scarcity. All groups rendering necessary services are producers. The question is not the elimination of middlemen but rather the rendering of the necessary services most efficiently and securing the most equitable reward of effort. While cooperative marketing offers advantages to the farming industry it can never be expected to make inefficient farmers prosperous. This raises the second point for consideration:—

2. Farm Organization and Management

The organization of farmers is important but we venture to suggest that the organization of farming is vastly more important. The fact that thousands may assemble to hear the organization of farmers discussed while those gathering voluntarily to listen to a discussion of farm organization may number only a corporal's guard by no means proves this statement wrong.

When any business becomes unprofitable reorganization usually takes place. This is also necessarily true of farming. The organization of farming means essentially the proportions in which land, labour, capital and management are brought together. The organization of farming is continually changing. During the past fifteen years circumstances have necessituated great changes. One development during that time is that a farm revenue which may have been reasonably sufficient fifteen years ago is today hopelessly inadequate. Greater revenue per farm is now necessary. In Canada the 1913 price of land still prevails. The cost of capital or the interest rate now approaches the prewar level. Farm wages—still none too high—are now almost twice the prewar level. We use sparingly that factor of production which is the most expensive. Hence during the post war period the more liberal use of land and capital and greater economy of labour have been necessary. This is just what has been taking place.

The Census Report of 1926 is interesting for two reasons. Not only does it furnish the most recent data available but it also reveals the reaction of farmers to the post war depression. The 1926 census covers only the three prairie provinces. During the five year period from 1921 to 1926, the number of farms in operation in the three provinces declined by 7,489 or by 3 per cent. The area of land occupied increased during that time by one million acres or 1 per cent. The improved area increased by four and a half million acres or 9 per cent, the cropped area by over two and a half million acres or 8.6 per cent. This amounts to a considerable reorganization of the farming business. The value of field crops of the three prairie provinces exceeded both in 1925 and in 1927 the value reached during the war years. This has been possible only by the cultivation of more acres. Fewer farms producing more.

The trend of the past half decade is but the acceleration of a movement which has been marked since the beginning of the century and particularly noticeable since 1911. At the beginning of the century the 511 thousand farms recorded employed some 700 thousand workers. At that time the surplus of exports over imports of farm products was around 50 million dollars per year in value. During the first decade the number of farms increased by 170 thousand, the workers in the industry by 200 thousand, while by 1911 the surplus of exports over imports amounted to about $100,-000,000. During the second decade there were less than 30 thousand farms added to the total number, the workers in the industry increased by slightly over 100 thousand while the surplus of exports over imports by 1921 reached $350,000,000. in value. Considerable of this increased value must be attributed to the change in price level. Yet making all necessary allowance for that the outstanding feature is that the value of product has increased in a ratio that is almost entirely out of comparison with the increase in number of farms or farm workers.

These figures reveal the fact which appears not to be generally recognized that there are at least two ways to expand the farming industry. One is by adding to the number of farms, the other is by increasing the product per farm. Which method of expansion will be in the best interest of those engaged in the industry? The answer would appear to be obvious. Which method of expansion should be followed in the interests of the country in general? This is a question upon which there may be ground for greater difference of opinion.

It would appear that there is only one way to secure cheap food and profitable farming at one and the same time and that is by not having too many engaged in the farming business. Let us examine this a trifle more closely. Slavery was unable to provide cheap food, serfdom was unable to get much farther in this direction, and the European peasantry have not achieved much along this line. The mechanized farming of this continent and Australasia has already contributed much in cheapening food and possibilities are as yet by no means exhausted.

Farm organization varies from country to country and from time to time. In Russia there are reported some 20 million farms and 145 million people or one farm for every seven. Is Russia contributing much to the world's food supply or is that country safe from famine? France with over 5 million farms and about 40 million people has one farm for every eight. That well farmed country is not noted for its contribution to the food supply of the world or for the high standard of living of its farmers. Denmark has some 205 thousand farms and three and a half million people or one farm to every fifteen. Denmark contributes considerable to the food supply of the world and farmers there are reported to compare favorably with those in other vocations in prosperity.

The United States with 6,300 thousand odd farms and 120 million population has one farm for every nineteen. Yet there appears to be no food shortage in that country. In fact the surplus of farm products appears to be more troublesome today with only some 26 per cent of the

workers engaged in farming than it was in 1820 when over 73 per cent of the workers were classed as farmers.

Canada has some 700 thousand farms and some nine and a half million people or one farm to every 14 approximately. And Canada has acquired quite a reputation as a food reservoir. This reputation has become indeed much enhanced since 1901 when over 40 per cent of the gainfully employed were engaged in farming; though at present we have nearly twice the population, only 40 per cent more farms and less than 33 per cent of our gainfully employed engaged in farming.

It appears that within certain limits and up to a certain point the fewer farms in comparison to total population the greater economy of food production—provided farms are equipped to allow efficiency. If this were not so we might be sending food products to Australia with all despatch for there 62 per cent of the population is classed as urban. Instead of that we find Australia a keen competitor in our own markets.

The more modern farm organization here as well as conditions elsewhere indicate that it is possible to have too many farmers both for the industry and the country in general just as it is possible to have too many coal miners, a condition which apparently prevails at present in many different lands.

These considerations raise a number of questions of considerable interest at the present time:—

(1) Do we need any expansion of the farming business in Canada at present?

(2) If farming be lacking in prosperity is it logical to increase the farmers' competitors?

(3) Should not the farmers have some say as to whether or not their competition should be increased?

(4) Should not those who are expected to insure the prosperity of the industry have more to say as to when, where and how the business should be expanded?

There appears to be small chance for any great difference of opinion on these questions. All will agree that the members of this association should take a more active part in the settlement of new lands in Canada than they have in the past. If this is not done this association will not be living up to its opportunities. This brings us to another phase of the subject which is:—

3. Land Economics

With the bulk of the land suitable for farming still to be settled, there is no country which has greater need for considering carefully the subject of land economics than Canada. Those who are responsible for carrying on the work are eager for information and assistance. Some concern has been expressed over finding work for technical agriculturists. They tell me at Ottawa that they would like to pay a man a reasonable allowance to have him analyse those interesting figures given in the hundred page introduction of Volume V of the 1921 Census. This work has not yet been done and already the quinquennial census of 1926 is becoming stale news.

This appears to confirm the claim made by Dr. Doughty of the Dominion Archives before the Royal Society—that no country had more complete records than Canada and few countries have made so little use of them.

It is only by careful study and analysis of conditions that it may be possible to avoid repeating past errors in land settlement, errors perhaps excusable in the past when there was less information available, but nevertheless now being corrected not without some expense to the public. More research on farm organization and land economics would be of invaluable aid toward the evolving of a desirable agricultural policy for Canada. It might contribute something to some of the more controversial questions before us at the present time.

If we are in agreement thus far another question follows. Is it in the best interests of the farming industry or the country generally that our immigration policy should stipulate that only farmers should be encouraged?

The farm organization prevailing has a very definite bearing upon this question of immigration. Few public utterances in this country appear to be complete without some reference to the question of immigration. I shall try to establish a precedent by not endeavoring to settle this question. One phase of this question appears to have so far however almost escaped attention. This is the bearing of the organization of farming on the population of the country.

The trend of the farming development of this century has been and is that the proportion of workers employed in farming is becoming continually smaller. If increased population be desired it appears from this that one certain way not to get it is the development of farming *only*. In the interests of the country generally and the farming industry in particular, industrial development, providing a home market for a greater proportion of our farm products, appears necessary. This is the only way population may be materially increased because modern farming organized on the growing of staple products for distant markets does not employ many people on the land. It does employ many making machines with which the farming is carried on. If these machines, from the brush cutters, which are sometimes used to prepare the land for breaking, right through to the comptometers which reckon the result, are built elsewhere the expansion of farming may not add greatly to the local population. I do not wish to be misunderstood on this point. This is not an argument for extensive methods *per se*. It is an argument for extending the farm income. When markets are distant extension of the farm income means usually the cultivation of many acres as we have noted.

If and when the farming business may have an attack of prosperity, even then the subject under discussion will not be entirely exhausted. This raises another question for discussion:—

4. Consumption.

The way revenue is expended is perhaps even more important than how it is secured. The public is continually exerting a keener interest in this matter. In this field the important question of rural education emerges. In the year 1921 the population of Canada was almost equally divided be-

tween urban and rural districts. Considering the age groups, however, we find that of those of 19 years and younger almost a quarter of a million more reside in rural than in urban districts. Of those of 60 years of age and older the greater number reside in rural districts. Hence of those between 20 and 60 years of age over a quarter of a million more reside in urban than in rural districts. The country must of necessity provide elementary education for a great number who when the stage of earning power is reached must go to urban centres to get a job. Moreover elementary education is more expensive in sparsely populated country districts than in crowded centres. Those centres which ultimately receive the benefit of this elementary training on account of the shifts in population may be required to contribute more to its provision. In the past the great dependence for securing revenue for municipal purposes for education as well as for other public expenditures has been the personal property tax. In rural districts this levy falls mostly on farm land. Recently securities have been better revenue producers than farm land—yet under the personal property tax they do not yield as much revenue to the public.

It is frequently maintained that living in country districts is much cheaper than in urban centres for the reason that rents are lower—and taxes form a considerable proportion of urban rent. Taxes are low in some country districts on account of the fact that improvements are not enjoyed. When the claim is made that the "cost of living" is lower in the country than in the city are we certain that we do not mean simply that in country districts it is not unfashionable to go without many things common to urban life? Brevity prevents elaboration of this theme but the need is obvious not only for increased revenue for farmers but also for the incorporation of this into higher standards of rural life.

When greater attention to agricultural economics is the trend in many countries, when Britain—a country with quite a reputation for neglecting farming—has an active association of agricultural economics, when the Bureau of Agricultural Economics at Washington has a personnel numbering over two thousand, and when the demand has been made in some of the provinces for strengthening this work in Canada, it is indeed a privilege to have the opportunity of supporting the establishment of departments where they do not already exist as well as the strengthening of those recently established.

VARIETE: FACTEUR INFLUENCANT LE POURCENTAGE D'ECALE DANS L'AVOINE*

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La performance des variétés d'avoine en ce qui concerne leur pourcentage d'écale a été étudiée depuis nombre d'années.

En 1891, Morrow et Hunt (*6*) de la Station de l'Illinois, mentionnent le fait que la variété Canadian Black possédait le plus haut pourcentage d'amande des variétés cultivées à cette Station, 78.1, le plus faible pourcentage, 58.81, étant obtenu avec la variété North Dakota Gray. En 1892, ces mêmes investigateurs (*7*) trouvèrent une différence de 16% entre les pourcentages le plus élevé et le plus faible de toutes les variétés essayées.

Zavitz (*11*) fait mention de la proportion d'écale suivante obtenue avec quatre variétés d'avoine cultivées durant six années:

	1902	1903	1904	1905	1906	1907	Moyenne pour 6 ans
Joanette	22.5	23.1	22.5	24.0	25.2	23.4	23.5
Daubeney	26.1	25.1	23.0	26.3	26.3	24.7	25.3
Early Dawson	32.6	33.7	32.4	36.0	38.1	33.7	34.4
Pioneer	48.1	36.8	36.9	36.8	42.8	38.8	40.0

D'après ces résultats on constatera qu'il y a une différence dans le pourcentage d'écale de 16.5% entre les variétés Joanette et Pioneer. La différence fut très marquée chaque année.

Leith et Delwiche (*3*) de la Station du Wisconsin obtinrent les résultats suivants pour deux variétés d'avoine:

	1913	1914	1915	1916	1917	1918	1919	Moyenne pour 7 ans
Ped, No. 7	24.11	34.2	27.48	30.0	27.2	29.7	26.59	28.4
Ped, No. 1	25.05	34.55	28.0	31.7	28.0	28.3	32.18	29.68

Encore ici il se rencontre quelques différences et, en 1919, la différence fut très marquée.

Love (*4*), à Cornell, admet cette différence dans la performance des variétés d'avoines. Il prouve sa constation en donnant le pourcentage d'écale pour les variétés essayées en 1912 et 1913, et par un graphique qui fait voir les grandes variations existant chez les différentes variétés.

Wiggans (*10*), à la même Station, trouve également des différences significatives entre quelques représentants de dix variétés morphologiques.

Love et Craig (*5*) appuient aussi cette même opinion, obtenant 75% d'amande avec la variété Cérnelian et seulement 64% avec la variété Mammouth Cluster.

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*Cet article est un extrait de la thèse présentée par l'auteur à la Faculté des Etudes Graduées et des Recherches, de l'Université McGill, pour l'obtention du degré de M.S.A. L'auteur désire exprimer ici sa reconnaissance aux Professeurs Summerby et Lods, du Département d'Agronomie du collège Macdonald, pour leur aide substantielle tant dans la compilation de ces données que dans la critique des présentes notes. Le texte original est l'anglais et la traduction est de l'auteur lui-même.

Summerby et Lods (*9*), du collège Macdonald, trouvèrent aussi des variations profondes dans le pourcentage d'écale d'un groupe de variétés essayées à cette Station.

Les résultats suivants furent obtenus par l'auteur dans l'étude des variétés individuelles: (Table 1).

Variété.	Moyenne du Pourcentage d'écale avec E.P.	Années d'essai.
Alaska (G)	22.99 ± .307	9
Daubeney (G)	25.52 ± .292	9
Banner (Dery)	29.10 ± .468	9
Joanette (G)	26.78 ± .915	8
Siberian (G)	27.99 ± .556	8
Banner (Dery)	29.31 ± .509	8
Fifty Pound Black	34.75 ± .816	8
Early Gothland (W)	30.53 ± .369	7
Banner (Dery)	29.24 ± .584	7
Early Blossom (I)	32.18 ± .439	6
Joanette (G)	27.49 ±1.119	6
Banner (Dery)	29.29 ± .691	6

Si l'on interprète ces résultats par ce qu'on est convenu d'appeler la méthode de l'"erreur probable de la différence", on voit que:

a) La variété Alaska est significativement différente de toutes les variétés essayées pendant 8 ou 9 années;

b) La variété Daubeney est significativement différente de toutes les variétés à l'exception de la variété Joanette;

c) La variété Joanette est significativement différente de toutes les variétés étudiées à l'exception des variétés Siberian et Banner;

d) La variété Siberian diffère significativement de toutes les variétés à l'exception de la Joanette et de la Banner;

e) La variété Banner est significativement différente de toutes les variétés à l'exception de la Siberian;

f) La variété Fifty Pound Black diffère significativement de toutes les variétés étudiées;

g) La variété Early Blossom diffère significativement des variétés Banner et Joanette pour une période d'années correspondantes.

Conclusion.

Il est de toute évidence que les variétés d'avoine diffèrent dans leur performance en pourcentage d'écale.

Type de la Panicule.

Les variétés d'avoine cultivées par toute la Province peuvent être classifiées en deux groupes principaux en ce qui concerne leur type de Panicule: le groupe à panicule étalée, de beaucoup le plus important, et le groupe à grappes sur un seul côté. (Le premier est connu en anglais sous le nom de "tree oats" et le second, de "side headed oats". Nous emploierons ces dénominations au cours du présent travail).

Morrow et Hunt (*6*) disent que les variétés du groupe "side headed" ont le plus fort pourcentage d'amande et dans la semence et dans la récolte. En 1892 (*7*), leurs conclusions restent identiques.

Bracken (*1*) établit que la qualité du grain des variétés "side headed" est inférieure, la semence ayant un faible pourcentage d'amande.

Summerby et Lods (*9*) admettent que généralement les variétés "side headed" ont un plus fort pourcentage d'écale.

La moyenne du pourcentage d'écale pour les variétés essayées au collège Macdonald, pendant des périodes d'années correspondantes et appartenant au groupe "tree" et "side headed", a été calculée et l'"erreur probable de la différence" a été employée dans les comparaisons. Les résultats obtenus sont les suivants:

Variété.	Type de la Panicule.	% d'écale et E.P.
Banner (Dery)	Tree	29.59 ± .631
Garton's Abundance	Tree	28.31 ± .328
Joanette (G)	Tree	27.56 ±1.149
Ligowo (E)	Tree	29.42 ± .541
Siberian (G)	Tree	28.35 ± .723
Bumper King (R)	Side Headed	28.05 ± .509
Early Gothland (W)	Side Headed	30.79 ± .381
Fifty Pound Black	Side Headed	33.15 ±1.069

Ces résultats sont compilés pour la période 1909-1916 et laissent voir de façon évidente un plus faible pourcentage d'écale en faveur du groupe "tree". Le pourcentage le plus élevé est obtenu avec la variété Fifty Pound Black qui se rattache au groupe "side headed". Mais si l'on considère la performance individuelle au moyen de l'"erreur probable de la différence" on en arrive aux conclusions suivantes:

a) La variété Bumper King n'est pas différente de:

1) La Banner, où la différence devrait être de 2.59% pour être significative;
2) La Garton's Abundance, où la différence devrait être de 1.94% pour être significative;
3) La Joanette, où la différence devrait être de 4.02% pour être significative;
4) La Ligowo, où la différence devrait être de 2.38% pour être significative;
5) La Siberian, où la différence devrait être de 2.83% pour être significative;

b) La variété Early Gothland n'est pas différente de:

1) La Banner, où la différence devrait être de 2.36% pour être significative;
2) La Joanette, où la différence devrait être de 3.87% pour être significative;
3) La Ligowo, où la différence devrait être de 2.11% pour être significative;
4) La Siberian, où la différence devrait être de 2.61% pour être significative.

c) La variété Fifty Pound Black est significativement différente de toutes les variétés "tree" étudiées.

Conclusion.

On ne peut dire que le type de la panicule est nécessairement relié à un haut pourcentage d'écale par les résultats obtenus, ou vice versa. La variété Bumper King, par exemple, possède une moyenne en écale qui n'est pas significativement différente de celle calculée pour les variétés du groupe "tree". Dans plusieurs comparaisons aussi la variété Early Gothland n'est pas différente. La variété Fifty Pound Black seule est significativement différente de toutes les autres variétés, mais encore en ce cas les différences ne sont que très peu marquées.

L'existence de l'hybride 0.113, collège Macdonald, peut être ici mentionnée. Il appartient au groupe "side headed" et donne en définitive une moyenne très faible en écale.

MATURITE.

Morrow et Hunt (*6*) trouvèrent que la proportion d'amande dans la semence et la récolte était la plus forte dans les variétés à maturité tardive.

Dans l'œuvre de Kiesselbach (*2*), on note que la moyenne de pourcentage d'écale dans les groupes hâtifs et tardifs varie de 28.5 à 32.9, indiquant une sensible différence entre les deux groupes.

Stoa (*8*) établit que les variétés hâtives, bien que fort souvent résultant en un faible poids au boisseau, ont une plus faible proportion d'écale que les variétés de demi-saison ou tardives.

Summerby et Lods (*9*) ont obtenu comme moyenne en amande pour les variétés tardives qu'ils avaient étudiées, 70.71%, mais 74.02% pour le groupe hâtif.

Toutes les variétés hâtives essayées au collège Macdonald furent comparées dans le présent travail à la Banner (Dery) et la Joanette, deux variétés tardives.

Essai pour une période de 9 années (1908-1911 and 1914-1918) :—

Classe.	*Variété.*	*Moyenne de % d'écale et E.P.*
Hâtive	Alaska	22.99 ± .307
Hâtive	Daubeney	25.62 ± .292
Tardive	Banner (Dery)	29.31 ± .508
Tardive	Joanette	26.78 ± .915

Essai pour une période de 4 années (1914-1917) :—

Classe.	*Variété.*	*Moyenne de % d'écale et E.P.*
Hâtive	Early Ripe Black	28.65 ± .3798
Hâtive	O. A. C. No. 3	24.50 ± .165
Tardive	Joanette	25.67 ± .428
Tardive	Banner (Dery)	29.47 ± .165

Essai pour une période de 3 années (1908-1910) :—

Classe.	*Variété.*	*Moyenne de % d'écale et E.P.*
Hâtive	Early Ripe (G)	25.93 ± .607
Hâtive	Early Prize Cluster	34.31 ±1.19
Tardive	Joanette	25.28 ± .718
Tardive	Banner (Dery)	29.77 ±1.141

Si l'on interprète ces résultats par "l'erreur probable de la différence, on voit que:

a) La variété Alaska est significativement différente et de la Banner et de la Joanette;

b) Les variétés Daubeney et O. A. C. No. 3 diffèrent significativement de la Banner;

c) Les variétés Early Ripe Black et Early Prize Cluster diffèrent significativement de la Joanette;

d) La variété Early Ripe (G) ne diffère ni de la Banner ni de la Joanette.

Ces résultats montrent évidemment:

1) Que le plus faible pourcentage d'écale se rencontre avec l'Alaska, variété hâtive;

2) Que quelques variétés hâtives ne diffèrent pas significativement des variétés tardives dans la proportion d'écale;

3) Que les variétés hâtives peuvent donner lieu à une forte proportion d'écale ainsi que c'est le cas pour la variété Early Prize Cluster.

Suit la performance d'un groupe de variétés comme démontrant un fait intéressant:

Variété.	*% d'écale.*	*Temps de maturité.* (Jours après le 1er juin).		*Années d'essai.*
			Lignée Banner (Dery)	
0.1512	24.38	81.0	83.3	1919–21–22
0.1712	22.82	86.5	85.5	1919–21–22–23
0.812	24.53	84.0	86.1	1921–22–23–24–25
Alaska	22.80	64.0	75.0	1906 à 1923
Daubeney	25.62	62.0	73.0	1906 à 1919
Banner (Dery)	29.70	.....	75.0	1906 à 1923

On voit que la lignée tardive 0.1712 possède un pourcentage d'écale aussi bas que l'Alaska, l'une de nos meilleures variétés hâtives commerciales, tandis que les deux autres lignées ont un pourcentage plus faible que la Daubeney qui est regardée comme une variété hâtive typique. Il ne serait pas sûr alors de prétendre que la hâtivité est reliée à un faible pourcentage d'écale et la tardivité à un pourcentage élevé, quand des exemples du contraire sont trouvés dans la présente étude.

TABLE I.

POURCENTAGE D'ECALE D'UN GROUPE D'AVOINES ESSAYEES AU COLLEGE MACDONALD.

Variéte	1908	1909	1910	1911	1914	1915	1916	1917	1918
Alaska (G)	24.23	22.05	22.17	25.48	23.47	22.05	22.32	22.12	21.60
Banner (Dery)	27.09	33.89	28.34	27.26	29.95	29.20	28.92	29.80	27.50
Bumper King (R)		30.43	27.43	30.19	27.06	27.38	25.80	26.92	
Daubeney (G)	25.09	24.89	24.16	29.37	26.05	24.21	25.08	26.07	25.68
Early Blossom (I)	32.03	31.66	34.86	30.33	33.39	30.84			
Early Gothland (W)	28.94	31.80	30.75	29.10	31.44	29.22	32.47		
Early Prize Cluster	31.20	37.30	34.42						
Early Ripe (Gérin)	24.31	27.42	26.07						
Early Ripe Black (G)			29.50		30.33	28.09	28.26	27.93	
Fifty Pound Black	33.80	39.26	35.58	29.41	39.44	32.48	32.72	35.35	
Garton's Abundance	28.85	30.32	28.00	28.16	27.72	26.80	26.99	27.05	
Joanette (G)	23.79	27.34	24.71	35.70	27.00	26.42	24.22	25.03	
Ligowo (E)	26.30	29.69	29.54	32.66	28.65	29.40	26.57	25.89	
O.A.C. No. 3					24.12	24.06	25.06	24.75	24.30
Siberian (G)	27.23	28.31	28.86	28.97	32.50	26.96	24.51	26.58	

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A TRAVERS LES REVUES

LA METHODE NEUBAUER POUR LA DETERMINATION DE L'ASSIMILABILITE DES ELEMENTS NUTRITIFS DU SOL.

Dans les articles de revues, concernant la fertilité du sol et les expériences de culture, il est souvent question d'une méthode, servant à estimer l'assimilabilité relative des substances nutritives du sol, portant le nom de Neubauer, son inventeur.

Plusieurs lecteurs seraient peut-être désireux d'avoir quelques renseignements sur le principe de cette méthode ainsi que certaines appréciations sur sa valeur pratique.

Nous trouvons dans les *Annales de la Science Agronomique,* numéro d'octobre 1927, un article intitulé: "Observations sur la méthode Neubauer", par L. Depardon, chimiste en chef du laboratoire départemental agricole de Châlons-sur-Marne, auquel nous empruntons les renseignements qui vont suivre.

L'auteur commence par rappeler que l'analyse chimique des terres, telle qu'elle est pratiquée ordinairement, laisse assez perplexe quant aux conclusions à tirer, parce qu'elle ne fait qu'indiquer le pourcentage des matériaux nutritifs solubles dans les acides forts. Elle ne nous dit donc rien concernant le degré d'assimilabilité des éléments.

Plusieurs méthodes ont été proposées pour établir aussi approximativement que possible cet état d'assimilabilité. Parmi elles, il y en a trois surtout qui ont retenu l'attention:

1° La méthode de Schloesing et Sigmond, basée sur la solubilité de P_2O_5 et K_2O par l'acide nitrique faible (N_2O_5 à 0.5%).

2° La méthode Bernard Dyer, basée sur la solubilisation de P_2O_5 et K_2O par l'acide citrique à 1%.

3° La méthode Neubauer, ou méthode des plantes en germination.

Les plantules en voie de germination ne vivent que peu de temps aux dépens des réserves contenues dans les graines. Aussitôt que celles-ci sont épuisées, les radicelles se mettent en devoir de prélever les matériaux nutritifs de la terre. Il en résulte que si on place sur une petite quantité de terre beaucoup de jeunes plantes en germination, leurs racines auront bientôt fait d'épuiser complètement les principes nutritifs solubilisables du sol, c'est-à-dire précisément ceux dont nous avons intérêt à connaître les proportions.

Pour cela, Neubauer fait l'analyse d'une nombre déterminé de plantules qui se sont développées dans cent grammes de la terre à analyser, jusqu'à épuisement de celle-ci. Ainsi, par exemple, il sèmera 100 grains de seigle dans les 100 grammes de terre fine sèche provenant du sol à analyser, après mélange avec du sable quartzeux (sable à verre) ; les plantules avec leurs radicelles, sont analysées lorsque leur jaunissement révèle l'épuisement du sol, ce qui a lieu au bout de 18 jours environ. En se basant sur un certain nombre d'essais, Neubauer indique les valeurs limites de diverses plantes, qui doivent être atteintes pour que les besoins en matériaux nutritifs soient satisfaits sans addition d'engrais.

Voici, suivant l'auteur, quelques-uns des nombres représentant les quantités de P_2O_5 et de K_2O que doivent prélever les 100 plantes en germination dans 100 grammes de terre diluée, ainsi qu'on l'a vu plus haut, dans du sable stérile.

	P_2O_5		K_2O	
Seigle, blé	8	milligrammes	14	milligrammes
Orge, avoine	7	"	18	2"
Trèfle rouge	9	"	29	"
Luzerne	13	"	34	"
Betteraves à sucre	12	"	39	"
Betteraves fourragères	14	"	60	"

Neubauer, après avoir fait le procès des méthodes chimiques, compare sa méthode avec les autres procédés physiologiques de mesure de l'assimilabilité des éléments du sol : l'essai en vases de végétation et les expériences sur parcelles en plein champs.

A l'avantage de sa méthode, il fait état de sa grande rapidité, l'analyse des jeunes plantules pouvant se faire au bout de 18 jours ; la facilité de sa réalisation, puisqu'il n'est pas indispensable de mettre à l'optimum tous les facteurs de croissance, l'eau et la chaleur étant seuls indispensables.

L'auteur ensuite expose les résultats auxquels il est arrivé après avoir expérimenté la méthode pendant deux années, en se conformant exactement

aux prescriptions de son inventeur. Afin de savoir si les prélèvements de 100 plantules dans le même sol étaient constants, tous les essais furent faits en double; les installations contenant les graines et les 100 grammes de terre étant placées sous une hotte vitrée, bien éclairée et maintenue à la température du laboratoire. Les résultats sont consignés dans deux tableaux, le premier donnant le nombre de milligrammes de P_2O_5 trouvé dans les jeunes plantules et, par différence avec la quantité de P_2O_5 contenue dans les cent 100 graines avant la germination, le nombre de milligrammes prélevé dans les 100 grammes de sol; le second établissant les chiffres correspondant pour le K_2O.

L'examen du premier tableau montre de grands écarts entre les essais faits en double, parfois même la quantité de P_2O_5 dosé dans les plantules ayant poussé dans le témoin (sable stérile) est plus élevée que celle trouvée dans les plantules qui se sont développées dans un sol bien pourvu de P_2O_5.

C'est pourquoi l'auteur conclut à l'inefficacité de la méthode Neubauer en ce qui concerne la détermination du P_2O_5 assimilable dans le sol. Pour le K_2O, au contraire, l'examen du deuxième tableau montre une fixité assez remarquable dans les quantités prélevées par les jeunes plantules au cours des essais faits en double. D'autre part, l'auteur trouve aussi une certaine corrélation entre ces exportations de potasse et les quantités de cet élément qui sont solubilisées sous l''influence de l'acide nitrique faible (méthode Dyer.) Aussi il conclut que la méthode Neubauer présente un réel intérêt à l'égard de la potasse. Avant de faire part des résultats de son expérience à lui, l'auteur donne aussi un certain nombre de conclusions plutôt défavorables à la méthode Neubauer, formulées par divers savants allemands, à la suite de leurs travaux.

H. M. N.

NOTES PERSONNELLES

Nous avons le plaisir d'annoncer le mariage de monsieur S. J. Chagnon. assistant-chef du Service de l'Elevage, au Ministère de l'Agriculture, a Québec, avec Mlle. Adrienne Beaudet; la bénédiction nuptiale a eu lieu à Ottawa le 31 juillet dernier.

Nous apprenons que monsieur Paul-Emile Sylvestre, élève finissant de l'Institut Agricole d'Oka, en juin 1927, vient d'obtenir le titre de "Master of Science" à l'Université de Madison, Wisconsin, où il faisait des études post-scolaires depuis le mois de septembre dernier. Nous adressons à monsieur Sylvestre nos meilleures félicitations.

BOOK REVIEW

American Chemistry, by Harrison Hale, Head of Dept. of Chemistry, University of Arkansas. (D. van Nostrand Company Inc., New York, N.Y., 1928. $2.50).

If any lingering doubt exists in the minds of laymen as to the vital importance of chemistry in modern every day life, here is a book calculated to dispel it. Sketchy by necessity because of the vastness of the author's task, the book is informative and written in non-technical language. The controlling influence of chemistry is emphasized in sanitation and medicine, food and fertilizers, in the publication of books and newspapers, in the manufacture of clothing and explosives, dyes and paints, oils and gasoline, lime and cement, solvents and precipitants, rubber, metals, bricks and china-ware and in all the electrochemical industries.

Though written from the standpoint of a citizen of the United States of America the statements made in this book hold good in great part for Canada. The book closes with a prophetic note as to the future and the part that must be played by chemical research in any nation which is to flourish and live. This book is written in plain language and the non-chemist as well as the professional chemist can get information and pleasure from reading it.

R. R. McK.

ERRATUM

On page 57 of the September issue of *Scientific Agriculture,* Article 17 of the C.S.T.A. by-laws was printed in an incomplete form. The following words should be added to complete the paragraph:—"remaining due by the Society."

VACANCIES IN DOMINION DEPARTMENT OF AGRICULTURE

The Civil Service Commission at Ottawa is advertising the following positions:—

Assistant to Chief Supervisor, Illustration Stations. (Bilingual). Headquarters at Ottawa. Initial salary $2,040 per annum, with increases of $120 per annum up to a maximum salary of $2,520. Applications close October 11th.

Senior Live Stock Promoter (temporary) for Dominion Live Stock Branch in Northern Alberta. Initial salary $2,040 with increases of $120 per annum up to a maximum salary of $2,520. Applications close October 9th.

Experimental Farm Superintendent, Grade 1, for Harrow, Ont. Post graduate training necessary, the major subjects of which dealt with tobacco production. Initial salary $2,220, with increases of $120 per annum up to a maximum salary of $3,120. Applications close October 18th.

CONCERNING THE C.S.T.A.

At this season of the year the finances of the Society are usually in rather a precarious condition due to the delinquency of many members in paying their annual membership fees. This year is no exception. The current C.S.T.A. year commenced on June 1st, 1928, and practically all renewal membership fees fell due on that date. Four months of the year have now passed and comparatively few members have paid their $5.00 fee. Perhaps this notice will be sufficient to remind all members who do not hold their annual cards for 1928-29, to send $5.00 now to their local secretary or direct to the General Secretary at Ottawa.

A membership campaign was launched by the Society early in September, and it is hoped that a sufficient number of new members will be added to the membership list to keep the total membership at approximately one thousand. Members can help greatly in this campaign by sending the names and addresses of prospective members to the General Secretary.

Applications for Membership

The following applications for regular membership have been received since September 1st:—

Christie, G. I. (Toronto, 1902, B.S.A., Iowa, 1925, D.Sc.) Guelph, Ont.

Maduke, J. H. (Saskatchewan, 1928, B.S.A.) Canora, Sask.

McBeath, T. C. (Alberta, 1928, B.Sc.) Lacombe, Alta.

McPhail, M. C. (Toronto, 1921, B.S.A.) Stratford, Ont.

Roy, A. (Montreal, 1928, B.S.A.) La Gorgendière, P.Q.

Rowell, H. P. (McGill, 1928, B.S.A.) Abbotsford, P.Q.

Salvas, Donat (Laval, 1927, B.S.A.) Richmond, P.Q.

Sabourin, R. P. (Montreal, 1928, B.S.A.) Ripon, P.Q.

Scott, Auguste (Laval, 1927, B.S.A.) Plessisville, P.Q.

Squires, W. A. (New Brunswick, 1927, B.A.) Fredericton, N.B.

Tait, G.M. (McGill, 1928, B.S.A.) Macdonald College, P.Q.

Thomson, L. B. (Alberta, 1925, B.Sc.) Medicine Hat, Alta.

Notes

Ernest Rhoades (McGill '12), formerly Assistant Chief of the Poultry Division, Dominion Live Stock Branch, Ottawa, and Secretary of the Third World's Poultry Congress, has been appointed Editor of Publicity and Publications for the Dominion Dept. of Agriculture.

Miss Maude A. Allen (British Columbia '26) is teaching Agriculture, English and History at the High School, Courtenay, B.C.

O. McConkey (Toronto '17) Lecturer in Field Husbandry at the Ontario Agricultural College, is spending the next year at Christ's College, Cambridge University, England, on special studies and research.

Victor E. Graham (Saskatchewan '27) has resigned his position as Instructor in Dairying at the University of Saskatchewan, to take graduate work in dairy bacteriology at the University of Wisconsin. His address is 728 University Ave., Madison, Wis.

F. B. Hutt (Toronto '23) who has been at the University of Edinburgh for the past year, has received the appointment of Asst. Professor of Poultry Husbandry at the University of Minnesota.

E. T. Chesley (Toronto '22) has resigned his position as Associate Editor of the *Ontario Farmer*. He is now with the Advertising Dept., Massey-Harris Company, Toronto.

P. Stewart (Toronto '14) has resigned as Secretary of the Canadian Seed Growers' Association to accept a position with the Canada Malting Co., Limited, with headquarters in the Royal Bank Building, Toronto. He will take up his new duties on November 15th.

Miss Helen Milne (British Columbia '27) has been appointed to organize the poultry courses at the University of Alberta, Edmonton.

R. W. Brown (Toronto '13), Professor of Dairy Husbandry at the Manitoba Agricultural College, has been granted leave of absence to take graduate work in the Department of Dairy Industry, Iowa State College, Ames, Iowa.

J. G. Davidson (Saskatchewan '4) has been appointed Asst. Superintendent of the Dominion Experimental Farm, Indian Head, Sask. He was formerly Instructor in Field Husbandry at the University of Saskatchewan.

W. M. Fleming (Alberta '19), Asst. Superintendent of the Dominion Experimental Station, Summerland, B.C., was married at Penticton, B.C., on July 18th, to Miss Ruth Marion Coley.

H. A. MacGregor (Alberta '28) is Instructor in Science at the Provincial Normal School, Camrose, Alta.

J. R. Fryer (Toronto, '13) Associate Professor of Genetics and Plant Breeding at the University of Alberta, is taking graduate work at the University of California. His address is 1144 Spruce St., Berkeley, Cal.

G. R. Wilson (Toronto '18) has been transferred as District Poultry Promoter, Dominion Live Stock Branch, from New Brunswick to British Columbia. His new address is 322 Winch Building, Vancouver, B.C.

E. B. Fraser (British Columbia '25) has been appointed Asst. Animal Husbandman at the Central Experimental Farm, Ottawa.